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TM 10-610

U.S. Dept. of Army

WAR DEPARTMENT

TECHNICAL MANUAL

REFRIGERATION

12 June 1943

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TECHNICAL MANUAL

REFRIGERATION

CHANGES No. 1

US WAR DEPARTMENT,
WASHINGTON 25, D. C., 13 September 1943.

TM 10–610, 12 June 1943, is changed as follows:

5. Heat.—*a. Definition.*

* * * * * * *

(2) When heat is * * * molecular motion increases. If a solid such as ice is heated, the rate of vibration of the molecules increases to a point at which the molecules break free from **the rigidity of the substance; thus the solid melts. If the liquid (water)** which results is heated further, the molecular motion increases in violence until the action becomes so intense that the liquid is broken up and boils or evaporates. If the gas * * * but will expand.

* * * * * * *

[A. G. 300.7 (30 Aug 43).] (C 1, 13 Sep 43.)

17. Operation and maintenance.

* * * * * * *

c. Maintenance.

* * * * * * *

(3) The addition of refrigerant liquid to an ammonia system has become a standardized operation. The liquid added * * * the expansion valve.

* * * * * * *

[A. G. 300.7 (30 Aug 43).] (C 1, 13 Sep 43.)

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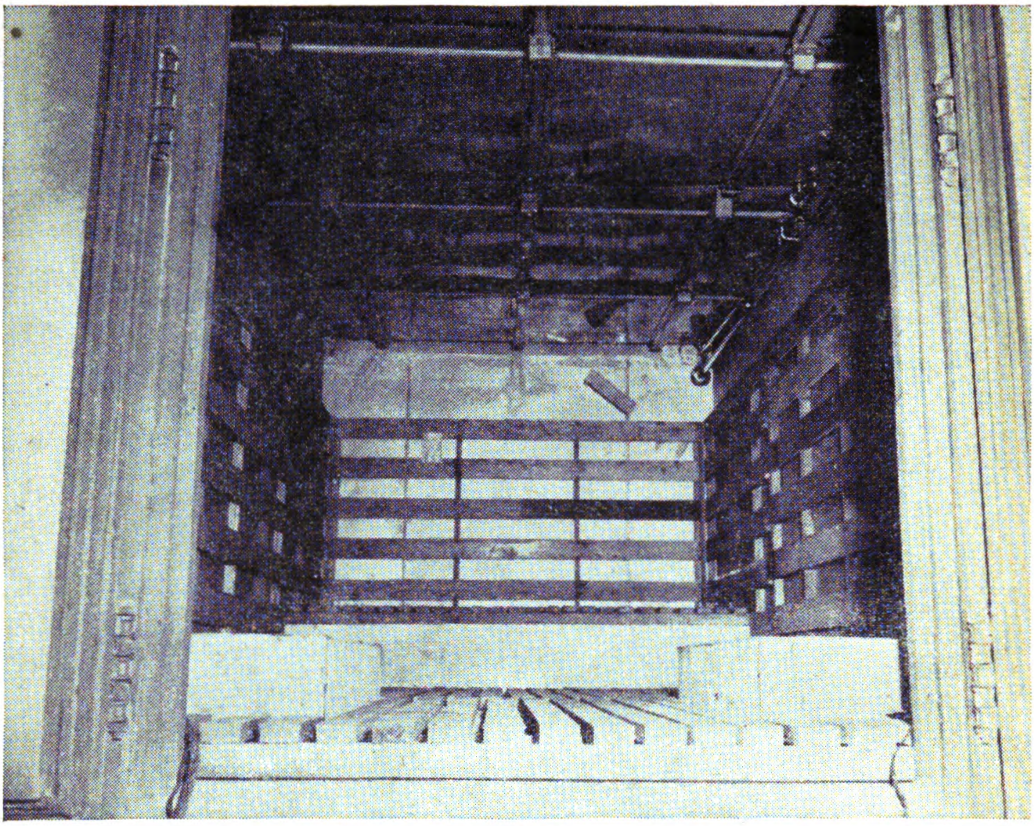

②

FIGURE 22.

[A. G. 300.7 (30 Aug 43).] (C 1, 13 Sep 43.)

BY ORDER OF THE SECRETARY OF WAR:

G. C. MARSHALL,
Chief of Staff.

OFFICIAL:

J. A. ULIO,
Major General,
The Adjutant General.

U. S. GOVERNMENT PRINTING OFFICE: 1943

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TECHNICAL MANUAL No. 10–610

WAR DEPARTMENT, WASHINGTON, 12 June 1943.

REFRIGERATION

*This manual supersedes TM 10–610, 1 October 1940.

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CHAPTER 1

PRINCIPLES OF REFRIGERATION

SECTION I

GENERAL

1. **Purpose.**—The purpose of this manual is to furnish detailed information and instruction to officers and enlisted men engaged in refrigeration activities.

2. **Scope.**—This manual includes information on—

a. Principles of refrigeration.

b. Methods of applying refrigeration principles through various types of equipment.

c. Analysis of the methods of operation and maintenance of refrigeration equipment.

d. Employment of refrigeration by the armed forces.

3. **Uses of refrigeration.**—Certain items of subsistence (such as meats, dairy products, etc.) and many medical supplies (serums in particular) will deteriorate in a very short time if exposed to normal temperatures. Their value as food or medicine must be protected. Refrigeration by natural or manufactured ice or by mechanical means is the medium used to create and maintain the temperature ranges affording this protection. Refrigeration can perform the following services:

a. Condition air, and thus improve working conditions.

b. Cool beverages and food, and thus make them more palatable.

c. Establish control of temperatures for industrial uses.

d. Preserve perishable foods and medical aids. For military purposes, this provides the greatest benefits. Refrigeration enables man to produce atmospheric conditions which retard or stop the life processes of such microorganizms as molds, yeasts, and bacteria; it controls the two essentials of their growth—warmth and moisture. This suspension of spoilage or deterioration permits prolonged use of perishables and their transportation over long distances from producer to consumer.

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SECTION II

BASIC PRINCIPLES

4. **General.**—"Refrigeration" is a general term used to describe the process of removing heat from an area or substance. The term is usually applied to artificial means of lowering temperatures. Since refrigeration deals entirely with the removal of heat, some knowledge of the nature and effects of heat is necessary for a clear understanding of the subject.

5. **Heat.**—*a. Definition.*—Heat is a form of energy, contained to some extent in every substance on earth. All the elements known are made up of extremely small particles called "atoms," which, joined together, form molecules. These molecules are peculiar to the form they represent; for example, carbon, and hydrogen in a certain molecular combination form sugar, and in other combinations form alcohol and gasoline.

(1) Molecules are in constant motion or vibration. Heat is a form of molecular energy which results from the motion of these molecules. The form of the substance containing the molecules dictates to a degree their activity. Conversely, the activity of the molecules will dictate the form of their combination; that is, as a solid, liquid, or gas.

(2) When heat is added to a substance, the rate of molecular motion increases. If a solid such as ice is heated, the rate of vibration of the molecules increases to a point at which the molecules break free from they represent; for example, carbon and hydrogen in a certain molec-which results is heated further, the molecular motion increases in violence until the action becomes so intense that the liquid is broken up and boils or evaporates. If the gas is heated, it will remain a gas but will expand.

(3) Heat cannot be destroyed or lost; but it can be transferred from one body or substance to another or to another form of energy. Since it is not itself a substance, it can best be considered in relation to its effect on substances or bodies. When a body or substance is stated to be "cold," the heat which it contains is less concentrated or less intense than the heat in some other body used for comparison.

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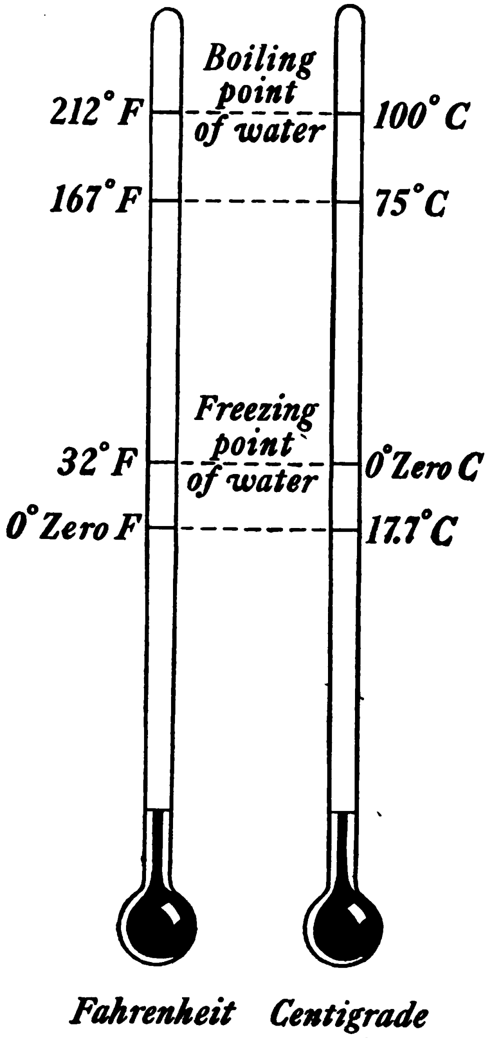
b. Temperatures.—Temperature is a measure of the intensity or level at which the energy of heat exists. The unit of temperature is the degree of Fahrenheit, usually written °F., or the degree of Centigrade, written °C. Both are based on the reaction of water to the addition or extraction of heat.



On the left are two thermometers, one Fahrenheit and one Centigrade. To illustrate the difference between the readings on each it will be necessary to know the bases of their graduations or markings. The basis of the marking or graduation in both cases is 1°, but these differ in value.

The Fahrenheit thermometer is marked with 180° between the freezing point (32° F.) and the boiling point (212° F.) of water, whereas the Centigrade thermometer uses only 100° between those two points. Therefore, each Centigrade degree is the equivalent of 1.8 Fahrenheit degrees. Fahrenheit readings will be 1.8 times as great as Centigrade readings in the zones between the freezing and boiling points of water. However, as the Fahrenheit temperature reading at freezing (0° C.) is 32° F. this figure must be added to the product of multiplying Centigrade readings by 1.8.

For example, a reading of 75° C. will be converted to Fahrenheit as follows: The 75° C. is multiplied by 1.8, the product being 135° F. To this must be added 32° F. (difference zero F. and zero C.) with a result of 167° F. Inspection of the drawing will show this operation. By the same method zero on the Fahrenheit scale will represent —17.7° C. on the Centigrade scale.

FIGURE 1.—Drawing of thermometer.

c. Thermometers.—(1) The usual means for measuring temperature is the thermometer, an evenly graduated (or marked) hollow tube, at the bottom of which is a bulb of liquid (usually a mercury solution). The nature of this liquid causes it to rise or fall uniformly in the hollow tube with each degree of temperature change. Thermometers are employed in the control of refrigeration.

(2) There are four types of thermometers in use today, but in all of them the unit for measuring temperature is the degree (°). On each of the four types, there are also fixed points which may be used

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for quick reference. These are the freezing point and the boiling point of water. The four types of thermometers are the Fahrenheit, Centigrade, Reaumur, and the Absolute (which may be graduated in either Fahrenheit or Centigrade increments). Of these, the two most common are the Fahrenheit and the Centigrade, which are explained below. The others are employed when calculations in refrigeration demand their use. For measurements of extremely hot or cold temperatures, specially designed instruments are used.

(*a*) *Fahrenheit.*—The Fahrenheit thermometer is graduated (or marked) with 180° between the freezing point (32° F.) and the boiling point (212° F.) of water. Experiments conducted at the time of the creation of the Fahrenheit thermometer indicated that the lowest possible temperature that could be reached was 32° F. below the freezing point of water. This lowest point was called "zero," and written "0° F." Since then, it has been found that at 459.6° F. below zero (commonly stated as 460° F. below zero, and written −460° F.) there is no longer any reaction of the atoms and molecules which give an indication of heat content, and therefore, to the best of our knowledge, total absence of heat. This point, 459.6° F. is called "absolute zero."

(*b*) *Centigrade.*—The Centigrade thermometer is graduated (or marked) with 100 graduations (or marks) between the freezing point (32° F.) and the boiling point (212° F.) of water. For comparison of the graduations on this thermometer and on the Fahrenheit. (See fig. 1.)

d. Heat flow.—Heat flows from bodies of higher temperature to bodies of lower temperature in the same manner that water flows down hill; and like water, it can be pumped up again to a higher level so that it may repeat its flow downward. When two substances of different temperatures are brought into contact with each other, heat will immediately start flowing from the warmer to the colder. The greater the difference in temperature between the two substances the faster will be the flow of heat. As the temperatures of both substances become more even, the flow of heat will tend to slow up, stopping altogether when temperatures are equalized. This characteristic of heat is utilized in refrigeration. Heat of air and substances in an icebox or heat in food to be preserved is transferred to the refrigerant, the colder substance. Heat can flow from one substance to another in three ways, or in a combination of the three, by radiation, conduction, or convection.

(1) *Radiation.*—(*a*) The transfer of heat from a hot body to a cold one across an intervening space is called "radiation." In this type of flow, no material substance acts as a heat carrier. Heat rays

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travel in a straight line, the energy at the source of the radiant heat determining the distances from the source at which the heat can be felt.

(*b*) Heat rays will pass through a transparent substance without warming it, and will deposit their heat units on opaque (solid or non-transparent) surfaces in their path. These substances will absorb and stop the heat rays in the same manner that a shield placed in rays of light will cast a shadow; and heat rays can be reflected in the same

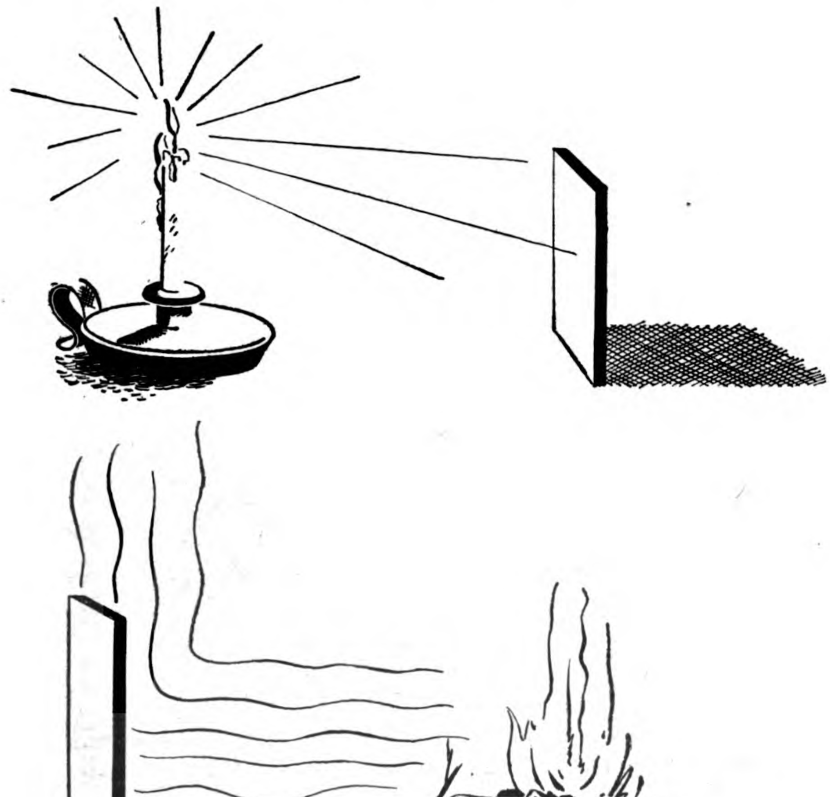

FIGURE 2.—Radiation and reflection.

manner as a mirror will pick and reflect light rays. Some insulation processes consist of the simple procedure of placing polished surfaces between the substances to be refrigerated and the sources of heat.

(2) *Conduction.*—In conduction, heat is passed along from one part of a piece of material to another part. An iron rod or pipe, one end of which is placed in a flame, will gradually become hot all over, the heat progressing from the fire through the bar or pipe. This progress of heat from one end of a bar to the other is called "conduction." The flow of heat by conduction may also occur along the flat surface of metal to any gas or liquid touching that metal. The rate

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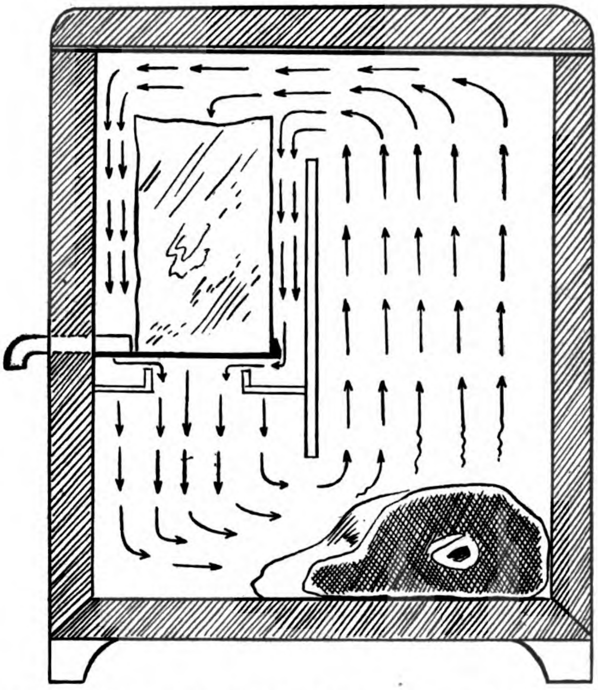
at which heat is conducted is dependent on the substance employed as a conductor. All metals are good conductors, though some are better than others. Other substances, such as stone and glass, are poor conductors, but these in turn are better than wood, hair, felt, or cork. The last mentioned substances are such poor conductors that they are used as insulating materials. (See par. 10*b*.)

(3) *Convection.*—Transfer of heat by the natural motion of the heated substance itself (whether liquid or gas), is called convection.



The convection cycle as illustrated above is shown in the most common form of application, the standard ice refrigerator. Here the air, warmed by the heat units radiated from the article to be cooled (meat, in this instance), rises to the top of the box, leaving a vacuum at the bottom of the compartment. As the warm air reaches the top of the box it is directed over and against the cooling medium—ice. Here it becomes colder and heavier and rushes down past the ice. It drops the absorbed heat units on the surface of the ice thus filling the void left at the bottom of the box by the rising warmer air.

FIGURE 3.—The convection cycle.

The utilization of convection heat flow is a fundamental operation in refrigeration. It is the transfer of heat from a warm body to a colder body by a fluid (liquid or gas) acting as a carrier between the two. In natural convection, the fluid absorbs heat from the warm body by actual contact (conduction), and becomes lighter and rises. The difference in temperature between the warm and cold bodies causes the carrier to circulate between the two, giving up its heat to the cold body, after which it becomes heavier and falls. The circulation of the carrier stops when there is no longer a difference in temperature, unless the carrier is circulated by mechanical means (forced convec-

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tion). This method of heat transfer requires that consideration be given to the path of flow of the carrier between the warm and cold bodies. The best heat transfer from one to the other is secured when the carrier fluid (whether liquid or gas has a free path with little obstruction and whether circulated by natural or mechanical means).

e. Unit of heat.—(1) The amount of heat added to or subtracted from a body can best be measured by the rise or fall in the temperature of a known weight of a substance. The standard unit of heat measurement is the amount of heat absorbed in raising by 1° F. the temperature of 1 pound of water, whose initial temperature may be anywhere between 32° F. and 212° F. Conversely, it is also the amount of heat that must be extracted to lower by 1° F. the temperature of a pound of water, initially between the same temperature limits. This unit of heat is called the British thermal unit, abbreviated Btu.

(2) Intensity and quantity of heat may be explained in the following simple way: the water in a quart jar and in a 10-gallon pail may have the same temperature and the same degree of intensity; but the number of Btu required to raise these amounts of water to a uniform temperature will differ greatly, the larger amount of water absorbing the greater amount of heat, the greater number of Btu.

f. Sensible heat.—Heat added to or subtracted from a substance without changing the state of that substance can be measured by a thermometer from the result of its action on the substance. This is known as sensible heat, because its presence can be detected by the sense of feeling.

g. Latent heat.—Latent heat is that heat which causes a change in the state of a substance. It is that quantity of heat in Btu which is needed to cause the change in state without changing the temperature. The temperature of a substance generally determines its form or state, as it indicates that at that temperature the latent heat has been added or extracted. Some substances may exist in three different forms or phases (solid, liquid, or gas) depending upon temperature and pressure. For example, water at temperatures below 32° F. exists as ice, a solid; between 32° F. and 212° F. it is in the common form of water, a liquid; and above 212° F. it exists as a vapor or steam, a gas. When the temperature is reached at which heat added or subtracted does not cause further change in temperature of a substance (as at freezing or boiling point), a change of state takes place. The heat necessary to cause 1 pound of a substance to change its state at the freezing or the boiling point is known as "latent heat."

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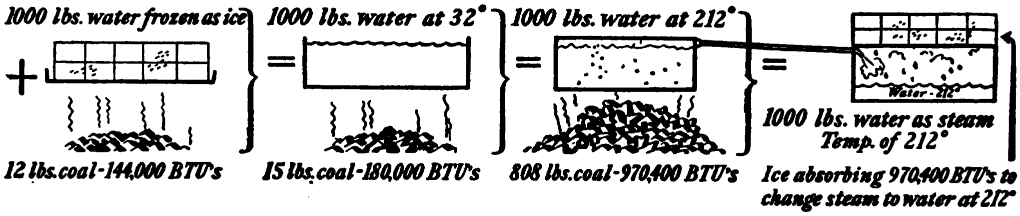
(1) *Latent heat of fusion.*—In changing from a liquid to a solid (water to ice) or from a solid to a liquid (ice to water), there is extracted or added respectively, 143.6 Btu (commonly stated as 144 Btu). This quantity of heat is called the "latent heat of fusion." To illustrate: in extracting Btu from 1 pound of water at a temperature of 33° F., the temperature is lowered (sensible heat) to 32° F. We then extract 144 Btu from the 1 pound of water, during which extraction the liquid changes to a solid, ice; but its temperature as read on a thermometer would remain at 32° F. Conversely, 144 Btu applied to 1



The above sketch shows 1,000 pounds of water frozen into blocks of ice about to be melted by a fire made to consume 12 pounds of coal. An average grade of coal, in burning, will release 12,000 Btu per pound. It requires approximately 144 Btu to change one pound of water (frozen as ice at 32° F.) to liquid at the same temperature. In order to change the 1,000 pounds of water frozen as ice to liquid it will require 144,000 Btu (1,000 pounds x 144 Btu per pound). As one pound of coal will generate, in burning, 12,000 Btu, 12 pounds of coal will be necessary to generate the 144,000 Btu.

In order to raise 1,000 pounds of water from 32° F. to 33° F., it will require only 1 Btu per pound of water, or 1,000 Btu for each degree of temperature change. To raise this water from 32° F. (freezing point) to 212° F. (boiling point) will require a temperature change of 180° or an addition of 180 Btu per pound of water, or 180,000 Btu. Again using the Btu generation factor for one pound of average coal (12,000 Btu per pound) it will require 15 pounds of coal. Example: 180° x 1,000 pounds of water =180,000 Btu÷12,000 Btu per pound of coal=15 pounds of coal required.

At the point 212° F., it will require 970 Btu per pound of water to change the water from a liquid to a vapor. This is the latent heat of vaporization. The fuel required in this change will be equivalent to the provision of 970 Btu for each of the 1,000 pounds of water or 970,000 Btu. Again using the 12,000 Btu per pound of coal, it is discovered that changing the 1,000 pounds of water to vapor at 212° F. will require 808 pounds of coal.

The latent heat of condensation is the extraction of Btu in the exact inverse order of the above-mentioned procedure in changing water to steam at 212° F. The steam on cooling will give up to the cooling agent (ice) the 970 Btu it absorbed on vaporization.

FIGURE 4.—Description of latent heat.

pound of water, frozen as ice, at 32° F. would change the state of the ice to 1 pound of water at a temperature of 32° F.

(2) *Latent heat of vaporization.*—The quantity of heat units that must be absorbed by a liquid to change its state to that of a gas at the same temperature, is known as the "latent heat of vaporization," or "evaporation." This value varies with different liquids under different conditions, temperatures, and pressures, but for illustration, use the liquid water. Water will boil at 212° F. Below that temperature, 1 Btu per pound of water is needed to raise it 1° of temperature. However, on reaching 212° F., the liquid ceases to change temperature;

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970.4 Btu must be added before any further change is obtained. The resultant change is in the state of the water, which has now become steam or water vapor at a temperature of 212° F.

(3) *Latent heat of condensation.*—The quantity of heat units that must be extracted from a vapor to change its state to liquid at the same temperature is known as the "latent heat of condensation." This extraction varies with different gases under different conditions, temperatures and pressures, so water vapor or steam is again discussed. From each pound of water converted into steam at 212° F., 970.4 Btu must be taken in order to restore it to its liquid state at 212° F. The action of condensation is an exact reversal of the act of vaporization. At the same pressures and temperatures, the amount of extracted heat is exactly the same as that added to vaporize the liquid.

h. Total heat.—Total heat is the sum of the sensible and latent heat loads. Since measurements of the total heat in a certain weight of a substance cannot be started at absolute zero, a temperature is adopted at which it is assumed there is no heat; and tables of data are constructed on that basis for practical use. Data tables giving the heat content of most commonly used refrigerants start at 40° F. below zero as the assumed point of no heat; tables for water and steam start at 32° F. above zero. Tables of data usually contain a notation showing the starting point for heat content measurement.

i. Specific heat.—Specific heat is a term used to express the ratio between the quantity of heat required to change the temperature of 1 pound of any substance 1° F. and the quantity of heat required to change 1 pound of water 1° F. The specific heat is thus numerically equal to the number of Btu required to raise the temperature of 1 pound of the substance through 1° F. For example, the specific heat of milk is .92, which means that 92 Btu will be needed to raise 100 pounds of milk 1° F., whereas 100 Btu would be needed to raise 100 pounds of water 1° F. The specific heat of water is 1 by adoption as a standard, and the specific heat of another substance (solid, liquid, or gas) is determined experimentally by comparing it with water. Specific heat expresses the heat-holding capacity of a substance compared to that of water.

TABLE OF SPECIFIC HEAT OF COMMON SUBSTANCES

Solids		Liquids		Vapors	
Ice	0. 504	Water	1. 00	Steam	0. 48
Iron	. 130	Grain alcohol	. 648	Air	. 24
Copper	. 095	Oil	. 45	Hydrogen	3. 4
Lead	. 031	Ammonia	1. 1	Ammonia	. 523
Glass	. 194	Isobutane	. 5	Methyl chloride	. 24
Brick	. 2	Methyl chloride	. 38	Isobutane	. 4

FIGURE 5.

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6. Pressure.—*a. Definition.*—Pressure is the rate of a uniformly distributed force exerted upon an area of a substance or substances. It is calculated by dividing the total force by the total area. The unit of pressure is generally expressed as pounds per square inch.

b. Atmospheric pressure.—Atmospheric pressure is pressure at sea level. It is expressed as 14.7 pounds per square inch absolute pressure, or 29.2 inches barometric (mercury column) pressure. As one ascends a hill, the atmospheric pressure will decrease; but below sea level in excavations or depressions, it will increase. Pressures under water differ from those under air only, because the weight of the water above is added to the pressure of the air.

c. Absolute pressure.—Absolute pressure is measured from absolute zero pressure rather than from normal, or atmospheric pressure. It

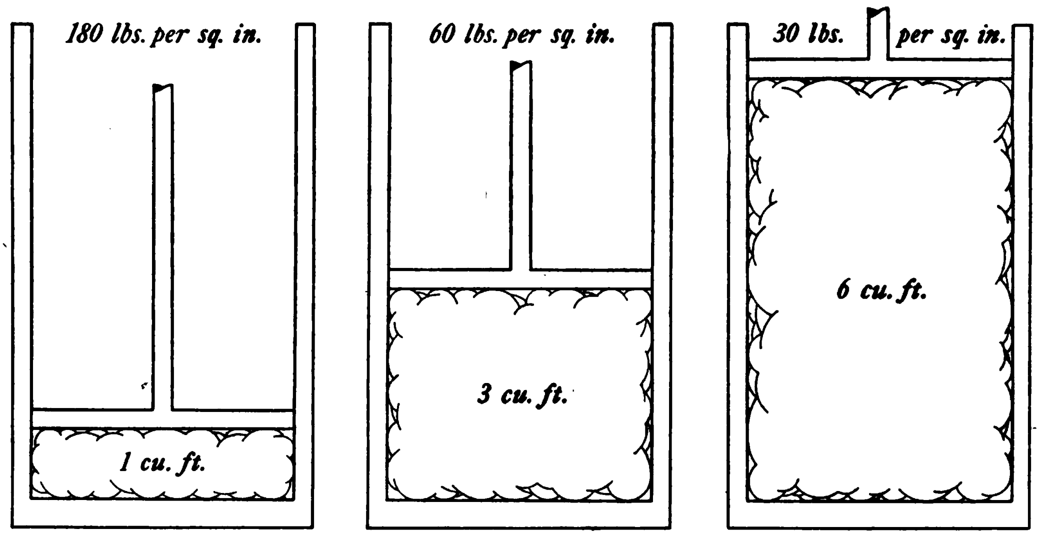

FIGURE 6.—Pressure on volume.

is equal to the atmospheric pressure (14.7 pounds per square inch) added to gage pressure.

d. Gage pressure.—Gage pressure is used on all ordinary gage scales, and is measured from and above atmospheric pressure. It is equal to absolute pressure less 14.7 pounds per square inch.

e. Effects of pressure.—(1) *On volume.*—The exertion of pressure on a substance will decrease its volume in proportion to the increase of pressure. Three cubic feet of gas is placed in a cylinder, and a piston exerting a pressure of 60 pounds per square inch is inserted in the open end. If the piston is pushed down into the cylinder and compresses the gas into 1 cubic foot, the pressure exerted would have to be 180 pounds per square inch. If the piston were withdrawn so that there were 6 cubic feet of the gas, the pressure would shrink to 30 pounds per square inch. (See fig. 6.)

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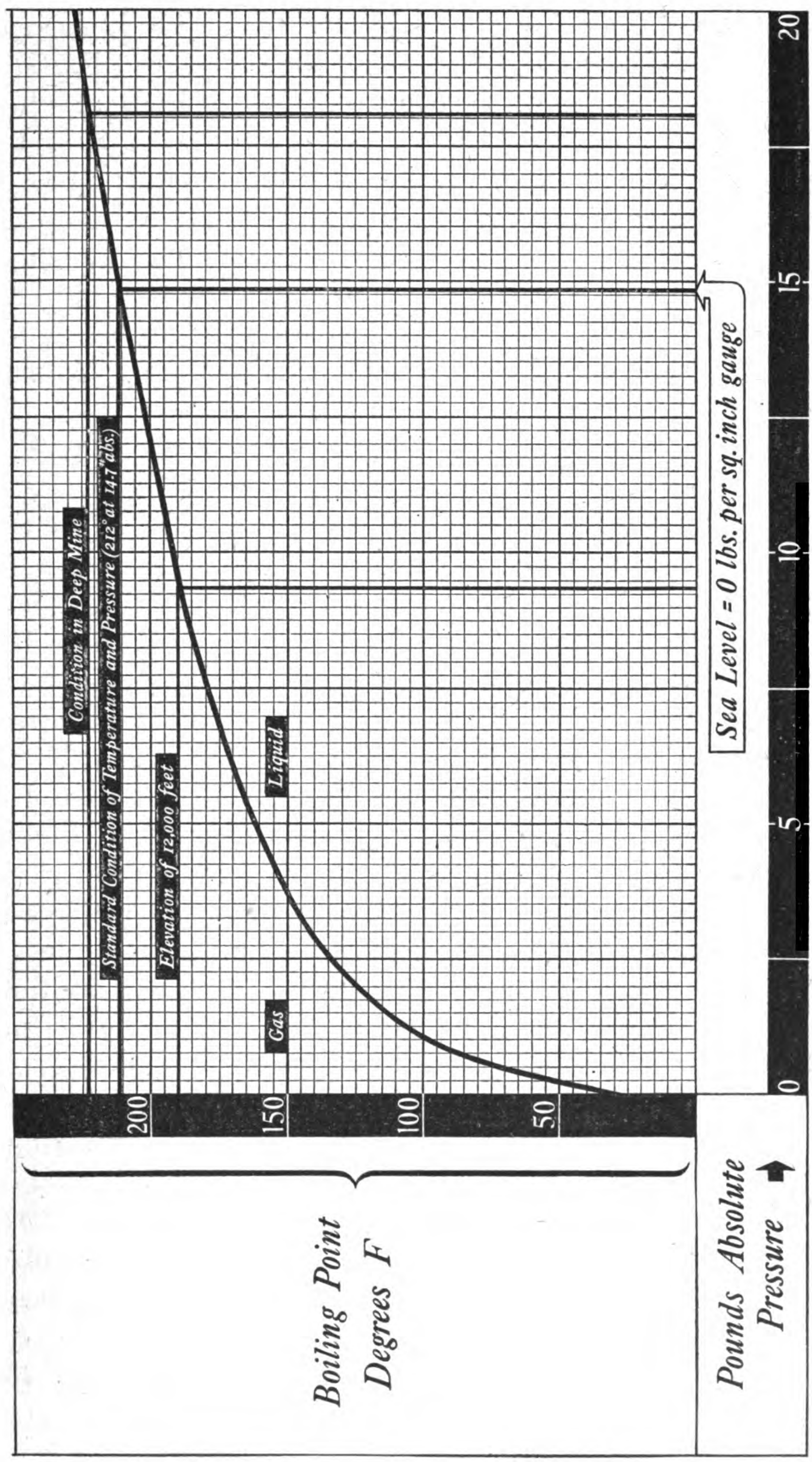

FIGURE 7.—Water vapor pressure curve.

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(2) *On vaporization of liquids.*—Pressure has a very definite relationship to the boiling point of any substance. There is a definite temperature at which a liquid will boil for every definite pressure exerted upon that liquid. Water which boils at 212° F. at atmospheric pressure (14.7 pounds per square inch absolute) will boil at 228° F. if the pressure is raised to 5.3 pounds gage pressure (20 pounds absolute). It will not boil until the temperature has been raised at 328° F. if the pressure exerted on the water is 100 pounds absolute (85.3 pounds gage). The same water will boil at 180° F. if a vacuum is created, which reduces the atmospheric pressure (14.7 pounds per square inch) to 7.5 pounds per square inch absolute pressure.

7. **Humidity.**—*a.* The amount of moisture the air can hold varies directly with increases or decreases of its temperature. An examination of figure 8 will make this relationship clear.

(1) *In cold storage rooms.*—The humidity here is a matter of great importance. Many products, such as meats, eggs, apples, etc., are very apt to shrink unduly when held in too dry an atmosphere. On the other hand, a high humidity furthers the growth of molds. Eggs that become moldy are even worse than badly shrunken ones. For the storage of such perishable products, care must be taken to maintain the optimum relative humidity in the storerooms. The desired humidity of cold storage rooms must be considered in conjunction with air circulation; the greater the velocity of the air, the higher should be the relative humidity. A storeroom with gravity circulation (one using the natural convection of air currents) may require a relative humidity of 80 to 86 percent to restrict mold growth; but with a good circulation (driven air), a relative humidity of 88 to 92 percent might be necessary to prevent excessive drying. The higher the humidity the less will be the shrinkage of products in the storage room, but the more the stored food will be likely to mold. The employment of humidity in storerooms depends primarily on the type of foods to be stored.

(2) *Dew point.*—The point at which air can hold no more moisture is called the "saturation" or "dew" point. The ability of air to hold moisture approximately doubles with every 27° rise in temperature. Air can hold $\frac{1}{160}$ of its weight of water at 32° F., $\frac{1}{80}$ at 59°F., and $\frac{1}{40}$ at 86° F. Dew point is the temperature at which moisture in air will condense if cooled at constant barometric pressure. If cooled to a point where the relative humidity (see fig. 8) reaches 100 percent, the moisture will be given up in drops of water, condensate. At that temperature the air has reached dew point.

(3) *Wet-bulb depression.*—The relative humidity in air can be determined by setting up on a board a pair of thermometers. The bulb of one of them is equipped with a wick saturated with water. Evap-

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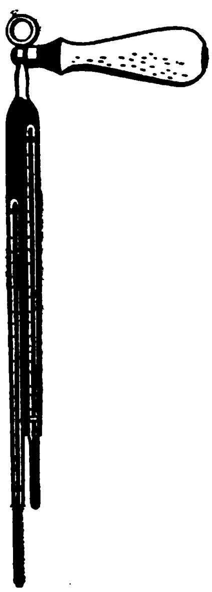
oration of the water will have a cooling effect, and the reading of the wet-bulb thermometer will fall below that of the dry-bulb thermometer. The difference between these readings (expressed in degrees) is called the "wet-bulb depression". By using the two temperature readings and referring to the chart (fig. 8), the reading in percent of relative humidity may be found.

(4) *Psychrometers.*—The two thermometers, arranged either on a fixed board or on a stick which can be whirled through the air, are called psychrometers. The latter device has an advantage in that rapid movement through the air will evaporate the moisture in the wet-bulb wick, and will thus indicate in a few seconds the wet-bulb depression.



Psychrometer

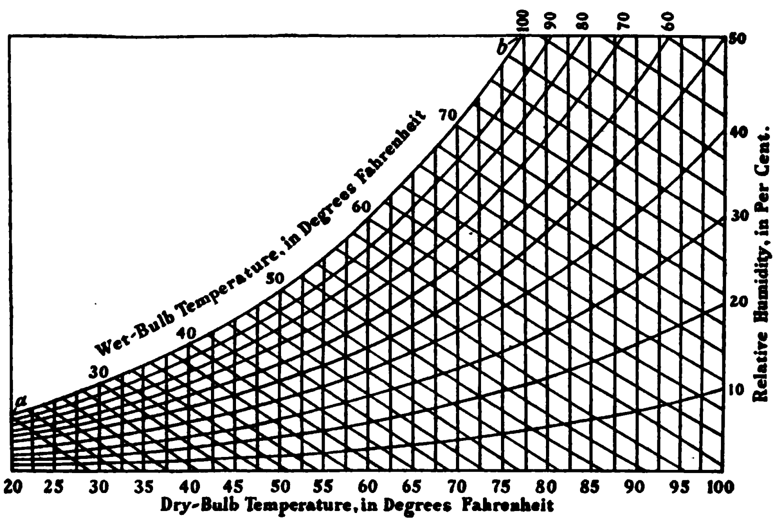


FIGURE 8.—Psychrometric chart.

Thermometers fixed on a board depend on the slower movement of air currents, and take a longer time to register.

b. Relative humidity.—(1) Relative humidity is the percentage of the maximum amount of water vapor or moisture which can be absorbed by air at a given temperature. It is determined by the wet-bulb depression or can be measured by a direct-reading hygrometer. A hygrometer usually employs hair or other material which is very sensitive to humidity change. (See fig. 8.)

(2) *Absorbents.*—In refrigerated rooms where the refrigerating coils or brine spray cannot dispose of the excess moisture, absorbents are frequently used. The most common of these are unslaked lime and calcium chloride. The latter is preferred, is highly absorbent, and will keep the average cold storage room dry. It is usually

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placed around the room in flat pans or troughs so as to expose the greatest amount of surface to the moisture-laden air. In many instances, these troughs are placed beneath the refrigerating coils or pipes to catch the condensed moisture dripping off them.

8. **Refrigerants.**—*a. General.*—(1) *Definition.*—That body, gas, or liquid which reduces heat is a refrigerant.

(2) *Principle.*—The principle of mechanical refrigeration is based upon the ability of refrigerants to absorb heat while in the process of changing from solids to liquids and from liquids to gases. Also, after those gases have been boiled from a liquid and have picked up all their latent heat of vaporization, they can be compressed by control of pressures, and condensed by removing the heat of compression and vaporization. Thus they return to their liquid state and assume their former heat absorptive ability. The hot gases are condensed by placing them in coils and pipes, over which may be passed cold air or water, which absorb and carry away the excess heat.

(3) *Efficiency.*—The efficiency of a refrigerant is based on numerous factors, the volume of area or the amount of substance to be cooled, the size of equipment used, the temperature at which the refrigerator is to be maintained, and the atmospheric conditions prevalent.

(4) *Properties.*—No refrigerant has all the desirable properties, but several have enough of them to be very satisfactory. The properties which should be found in the most desirable refrigerants are:

(*a*) A boiling point at atmospheric pressure as close as possible to the degree of refrigeration required. This means that some refrigerants are better suited to certain uses than others.

(*b*) High density gas.

(*c*) High latent heat (high absorption factor).

(*d*) Noninflammability.

(*e*) Noncorrosive action on metals.

(*f*) No undesirable action on oil.

(*g*) No undesirable physiological effects.

(*h*) Simple detection and control of leaks.

(*i*) Low cost.

b. Primary refrigerants.—There are many refrigerants with varying numbers of the properties listed in (4) above. But the most common are Freon-12, carbon dioxide, ammonia, and sulphur dioxide; of these, Freon-12 and ammonia are most extensively used. A primary refrigerant is one which changes its state upon the application or absorption of heat, and which in this act of change absorbs and extracts heat from an area or substance. The primary refrigerant is so termed because its action is direct upon the area or substance, although it may

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be inclosed within a system. Ice, solid carbon dioxide, and the refrigerants mentioned above fall into this class. These primary refrigerants have been selected because at atmospheric pressure they will begin to change state at low temperatures. This means that if no pressure is exerted upon them, they will absorb heat units until the area in which they are allowed to expand will have been reduced to the temperatures at or below which they will no longer vaporize or melt. Below is given a list of the temperatures (boiling points) at which these refrigerants will cease absorbing heat units:

Carbon dioxide	109° F. below zero.
Ammonia	28° F. below zero.
Freon-12 (dichlorodifluoromethane)	21° F. below zero.
Sulfur dioxide	14° F. below zero.

If the above-mentioned refrigerants are used without control, they absorb heat from most perishables to the extent of freezing them solid and rendering them unfit for use. Therefore, most of them are placed in systems in which they can be controlled by pressure, enabling them to carry on their absorption function at the temperature ranges desired. In figure 9 is given a table of the above refrigerants which gives the pressures necessary to maintain their evaporation (boiling point) at specified temperatures. From this table it is noted that while most refrigerants function alike, they do so under different pressure-temperature conditions; therefore, no refrigerant other than the one for which a refrigeration machine was designed (or so built that it can be adapted to change) should be used in that machine.

ABSOLUTE PRESSURE (POUNDS PER SQUARE INCH)

Boiling Point (°F.)	Dichlorodifluoromethane (CCl_2F_2)	Carbon dioxide (CO_2)	Ammonia (NH_3)	Sulphur dioxide (SO_2)	Ethyl chloride (C_2H_5Cl)
−10	19. 2	257. 3	23. 7	7. 9	3. 2
0	23. 9	305. 5	30. 4	10. 3	4. 1
10	29. 3	360. 2	38. 5	13. 4	5. 4
20	35. 7	421. 8	48. 2	17. 2	6. 9
30	43. 2	490. 8	59. 7	21. 7	8. 7
40	51. 7	567. 8	73. 3	27. 1	10. 8
50	61. 4	653. 6	89. 2	33. 4	13. 3
60	72. 4	748. 6	107. 6	40. 9	16. 3
70	84. 8	853. 4	128. 8	49. 6	19. 9
80	98. 8	968. 7	153. 0	59. 7	24. 2
90	114. 3	(*)	180. 6	71. 2	29. 2
100	131. 6	------------	211. 9	84. 5	34. 6

* Critical temperature 87.8° F., critical pressure: 1.070 pounds per square inch absolute.

FIGURE 9.

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(1) *Freon-12.*—A refrigerant much used in post refrigerators and mobile and field units of the armed forces is dichlorodifluoromethane (CCl_2F_2) or Freon-12, often called Freon. This refrigerant has a boiling point at atmospheric pressure of 21.7° F. It is practically odorless, and is harmless to breathe except in extremely concentrated form. It will not support respiration nor combustion, and is not inflammable. When dry, Freon-12 has no corrosive effect on copper, copper alloys, iron, or steel. It is meeting with considerable approval and is being used almost exclusively in new installations of moderate size. Freon-12 has an affinity for oil, and is immiscible (does not blend) with water which makes it necessary to use precautionary measures of control.

(2) *Ammonia.*—Ammonia is produced by the dry distillation of coal or other nitrogenous matter. It has the highest latent heat (absorption power) of any of the common refrigerants. It is corrosive to copper in the presence of oxygen. It does not support combustion but may form an explosive mixture with oil vapor or mixtures of foreign gases under high pressure. It is a gas with the formula NH_3, and is lighter than air. It is a powerful heart stimulant, but while it is extremely irritating to the mucuous membranes of the respiratory tract and the eyes, it is nontoxic. In the strictest sense, it can result in fatal injury. It is not ordinarily inflammable, but in certain concentrations with air it will ignite. It is widely used because of its low cost and because the operating pressures for protective temperatures are not high. Because of its odor, leaks are easily detected. It is immiscible with oil and is soluble in water which makes it easier to control its liberation from these substances. Ammonia is used almost exclusively in larger installations such as cold-storage warehouses, packing-house coolers, freezers, etc., where as much as 70,000 pounds of the liquid may be used; however it has also been used, though rarely, in household refrigerators requiring only 2 pounds.

(3) *Carbon dioxide.*—Carbon dioxide (or carbonic acid gas) is used to some extent in small commercial systems. However, it is liquefiable only under high pressures (about 1,100 pounds per square inch), and is therefore unsatisfactory for use in such small refrigerating machines. Carbon dioxide in solid form (dry ice) is utilized in some commercial transportation equipment when temperatures below freezing are required for the movement of frozen products. It sublimes (vaporizes into gas) directly from the solid until the temperature of the space into which it has been placed is lowered to its vaporizing point, or until it has completely vaporized. Its efficiency is impaired by any accumulation of water frost which tends to insulate it from the air. As it has no odor, leaks must be discovered by the use of limewater, or

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through addition of an odorous oil, such as oil of peppermint or cloves. The reaction of limewater to CO_2 is a white precipitate of calcium carbonate.

(4) *Sulfur dioxide.*—Sulfur dioxide is used as a refrigerant in a number of small refrigerating systems. It has several disadvantages, chief of which is that it corrodes metals if any moisture is present; it has a pungent odor, is suffocating, and is intensely irritating to the respiratory system. Although its properties include the ability to refrigerate under low pressures, the fact that leaks in the system will cause considerable damage and spoilage to foodstuffs makes it an undesirable refrigerant.

c. Secondary refrigerants.—Secondary refrigerants are those which in themselves are not refrigerants, but have been cooled, passed over or around the areas or substances to be cooled, and returned with their burden of heat units to the primary system where they are again cooled and resume their cycle of operation. Refrigerants in this class are cooled air, cold water, and brine used in brine sprays or brine coils.

d. Saturated refrigerants.—When a refrigerant arrives at a temperature at which it will vaporize, and during this process of vaporization, some portions will have been vaporized, while others are still liquid. At this temperature (which will vary with pressures on the refrigerant) both liquid and vapor can exist together, and the condition is said to be "saturated." Vapor containing particles of liquid is said to be "wet," but if vapor at its boiling temperature contains no liquid particles, it is said to be "dry and saturated." If the temperature of a vapor is raised above its saturation temperature, it is "superheated." Strictly speaking, saturated vapor, either wet or dry, is a "vapor" and not a "gas" until the vapor is superheated. But differentiation between "gas" and "vapor" is so slight that they are used almost interchangeably.

9. Application of principles.—The use and application of the characteristics of heat, pressure, humidity, and the properties of refrigerants is called refrigeration. These various characteristics and properties used singly or in controlled combination will perform the function of heat removal in the manner described below.

a. Refrigeration by natural means.—(1) Nature is continually striving to equalize differences in temperature. Heat flows from warm substances to colder bodies. Convection currents of air and water continually absorb and carry away heat from warm to colder substances. Warm air seeks the higher levels and allows the colder air to move into the lower levels. Evaporating water absorbs heat.

(2) Early methods of refrigeration were crude, utilizing the natural facilities at hand and employing unconsciously the basic prin-

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ciples of heat flow, radiation, and convection. Perishables were buried in the unwarmed, unthawed, or cold subsoils, submerged in the cold flowing water of springs or streams, and placed in the path of cool winds blowing through caves. The first improvements were dictated by the need for sanitation, and foods were put into crude containers which were then placed in the ground, stream, or air current. Still later developments and the discovery of the refrigerant properties of ice led to placing the refrigerant in the container with the substance to be cooled—the first crude refrigerator. Some of the early methods are still used by people in remote portions of the earth, and the military should keep these methods in mind as field expedients.

b. Refrigeration by use of solids.—(1) *Fusion of ice.*—(*a*) The solid most commonly used for refrigeration is ice, either natural or manufactured. Analysis of the properties of ice early revealed that it possessed a melting point sufficiently low to make it suitable for use as a refrigeration medium. Its suitability lies in its power to absorb heat units in melting while at the same time maintaining its own low temperature. Ice and mixtures of ice and salt are widely used for domestic food preservation, for commercial shipment and storage for articles which need refrigeration. Such commodities as fish, lettuce, celery, etc., require a high relative humidity to maintain their freshness and are frequently packed in cracked ice.

(*b*) The usual procedure is to put ice into an insulated compartment, icebox or refrigerator, into which the commodities to be refrigerated are also placed. These perishables radiate their heat to the air in the compartment, and as the air warms it rises (see fig. 3), circulates over the ice, becomes cooler and heavier, and sinks to the bottom of the compartment. The ice absorbs the heat units from the warmed air and the food gases (odors) which the air may have picked up from contact with the food. These gases are deposited on the thin film of melted ice water lying on the surface of the ice; as this water is drained off, the odors are drained with it. In a properly constructed refrigerator (see fig. 3) the convection cycle of the air not only serves to maintain refrigeration, but by the absorption of odors, prevents one commodity from contaminating the other.

(2) *Fusion of mixtures.*—Where the temperature required is lower than that of the melting point of ice (32° F.), and no power supply or equipment is available for producing refrigeration mechanically, a mixture of salt and ice will produce temperatures as low as 50° F. below zero. The usual mixture of salt (sodium chloride) and crushed

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ice melts into a liquid which absorbs an amount of heat equal to the total latent heat of fusion of both the ice and salt. The progressive addition of a 23 percent salt mixture will lower the melting temperatures to −6° F. The use of a calcium chloride mixture will produce extremely low temperatures. (Mixtures of solid carbon dioxide and acetone will produce temperatures as low as −70° F.) Mixtures are used in the bunkers of railway refrigerator cars for the preservation of frozen commodities, ranging from 5 to 30 percent added salt content.

(3) *Sublimation of solids.*—(*a*) Refrigeration by sublimation is a process of cooling in which the substance used (generally solid carbon dioxide, otherwise known as "dry ice") changes directly from a solid to a vapor without ever actually being in a liquid or melted state. In this method, use is made of the latent heat of vaporization as well as the latent heat of fusion.

(*b*) The prime commercial use of this method at present is for refrigerating ice cream which is being transported. Owing to the cost of production and the extremely low melting point (−109° F.) it is not frequently used for bulk shipments nor for refrigerating commodities that would be damaged by so low a temperature. The advantage of refrigeration by sublimation of solid carbon dioxide is that it permits dry packing and shipping.

c. Refrigeration by vaporization of liquids and gases.—(1) *Principle.*—Refrigeration by the vaporization of liquids and gases is based upon the fact that, in the absorption of heat units from a substance, the liquid is boiled into a gas and continues to absorb heat units in expansion. After the gas has expanded, it can be compressed, cooled, and condensed into a liquid, and it is then ready for reuse.

(2) *Effect of temperature on gases.*—For illustration, ammonia is used. Figure 10 is a sketch of liquid ammonia (NH_3) in an open flask whose base is inserted into an insulated compartment. If the temperature of the air and the insulated area were −28° F., the ammonia would be inert; that is, there would be no action. But should the temperature rise even 1°, the ammonia would begin to vaporize, absorbing about 591 Btu (590, the latent heat of vaporization of ammonia, plus 1 Btu.) This change is shown by the action in the flask in Figure 10②. If the temperature of the insulated compartment were 0° F., the ammonia would boil violently (absorbing about 618 Btu) until the compartment shown in figure 10③ is lowered to −28° F. (as in fig. 10④).

(3) *Effect of pressure on liquid and gases.*—In figure 11, the flask has a stopper in the neck and a valve which can be turned on or off. This figure illustrates the effect of pressure on the vaporization of ammonia gas. In figure 11①, the flask valve is open and the action

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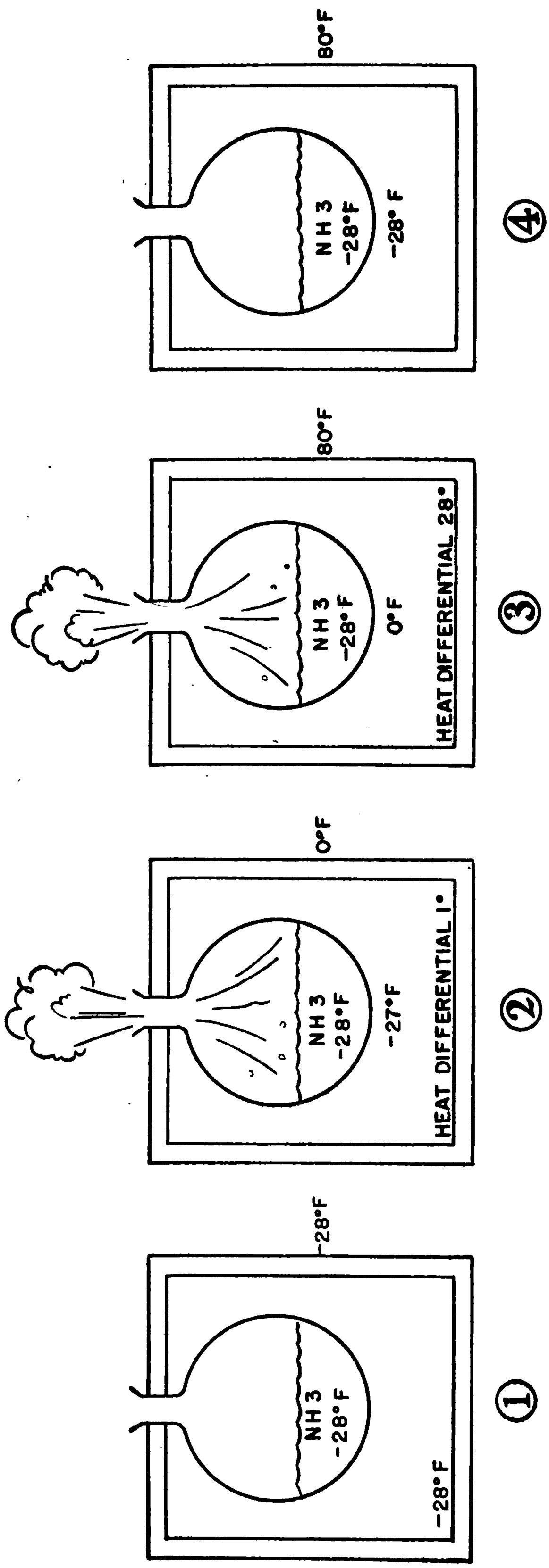

FIGURE 10.—Reaction of liquid ammonia at atmospheric pressure.

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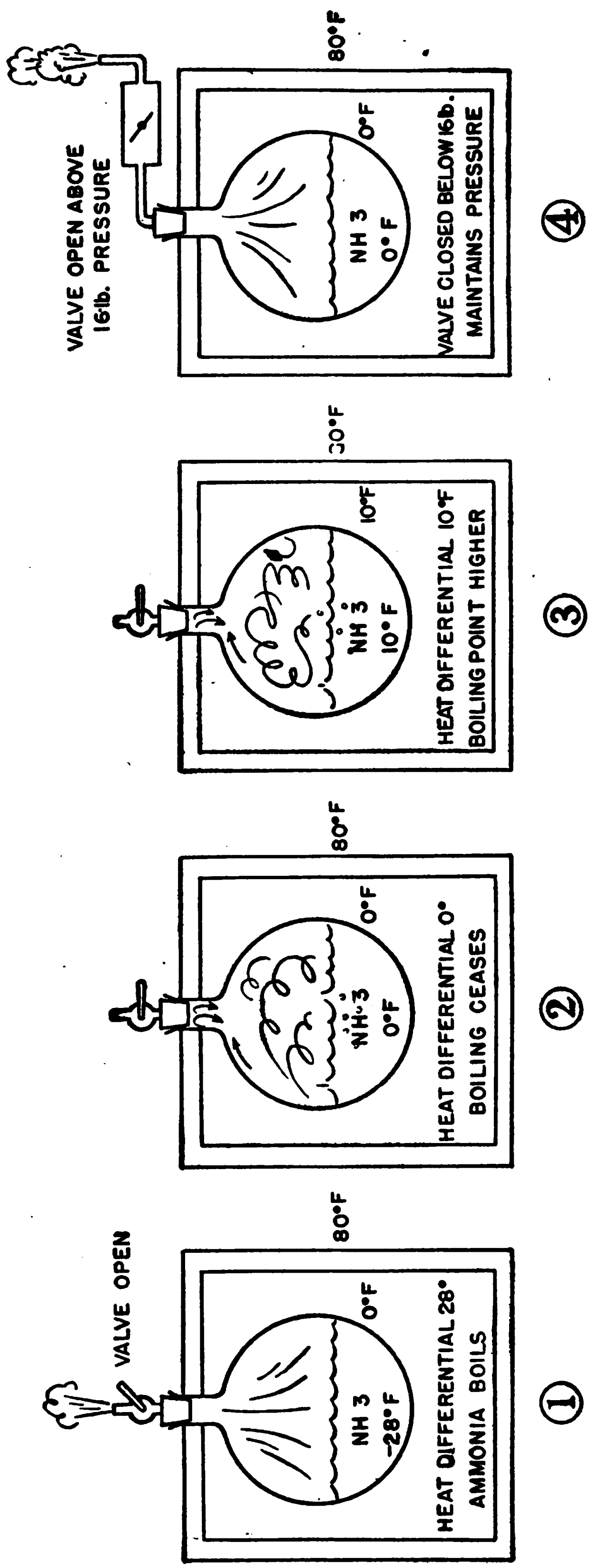

FIGURE 11.—Reaction of liquid ammonia under applied pressure.

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will be the same as in figure 10(3). The gas will vaporize and escape, cooling the compartment to $-28°$ F. However, it is desired that the compartment be cooled only to 0° F. Figure 11(2) shows the same flask with the valve closed. As the gas vaporizes, it continues to absorb heat units which cause it to expand. The expansion confined in the flask causes the pressure to increase, which in turn causes the boiling point of the gas to rise (see fig. 12). Consequently, when the pressure has reached 16 pounds per square inch gage, the boiling point of the liquid ammonia will be 0° F. When the temperature in the compartment reaches zero, the liquid will cease boiling and become inactive until the pressure drops or the temperature goes higher. The pressure increase in the flask, however, must be controlled if the temperature in the insulated compartment is to be controlled. In the action in figure 11(2), no consideration is given to the fact that the pressure in the flask may become greater than 16 pounds gage, which would cause the ammonia liquid to cease boiling at a higher temperature, as in figure 11(3) where the pressure has reached 25 pounds gage and the boiling point at this pressure is 10° F. If the valve were set to open (as in fig. 11(4)) when the desired pressure (16 pounds in fig. 11(2)) was exerted against it, and to close when the pressure lessened, the flask pressure would be maintained and the ammonia would absorb heat units as long as a temperature above 0° F. prevails in the compartment. The cost of ammonia is relatively low, but the process of cooling by the evaporation of ammonia becomes expensive when the liquid is permitted to boil away into the air. In addition, the need for constant replacing of ammonia in the system and the impossibility of working in the vicinity of escaping gas lead to one conclusion: capture the vaporized gas and reuse it. The retention and reuse is accomplished by the vapor compression system (fig. 13).

(4) *Vapor compression cycle.*—Mechanical refrigeration utilizes the properties and characteristics of refrigerants described above, and by controlling the action of the refrigerant and inclosing it in a system, can cool substances and areas to within a few degrees of the desired temperatures. The refrigeration equipment required for various refrigerants is constructed on the same principles, regardless of the refrigerant used. The main differences result from the different pressures required to produce alternate vaporization and liquefaction of the various refrigerants. Figure 13 shows a basic mechanical refrigeration system. There are four essential parts in the mechanical refrigeration cycle:

(*a*) The evaporator *A*, where the refrigerant boils in absorbing heat. The evaporator is located in the space where cooling is to be

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accomplished, and is arranged to provide for natural or forced circulation of the secondary refrigerant or heat carrier.

(*b*) The compressor *B*, where the refrigerant gas is compressed and its temperatures elevated so that it can give up the latent heat of vaporization absorbed in the evaporator.

(*c*) The condenser *C*, where the latent heat in the gas is given up, carried away by the cooling medium, and thereby changed again to a liquid. The condenser and compressor are really refrigerant-reclaiming devices, since a drum of refrigerant liquid connected to the expansion valve would provide refrigeration if the opposite end of the evaporator were opened to the atmosphere. The condenser and compressor will vary in size with the volume of refrigeration desired.

(*d*) The expansion valve *D*, through which the pressure of the refrigerant liquid is reduced so that it can begin its process of absorbing heat in the evaporator. The expansion valve will be set to release liquid at the pressure at which the refrigerant will absorb all heat units above the temperature desired in the cooling space. Adjustment of the valve by means of screw plugs, caps, or stems capable of manual manipulation permits the maintenance of a definite pressure condition in the evaporation. Any tendency toward pressure decrease would result in the valve's opening wider and admitting a greater quantity of liquid, until pressure approached the valve setting; then the quantity admitted will decrease. The fluctuation of quantity of refrigerant admitted will vary with the refrigeration load.

(5) *Pressure-temperature factors.*—A study of figure 13 will show the temperature-pressure curve of ammonia at varying degrees of pressure and temperature. Ammonia liquid (as indicated by the chart) at a pressure of 40 pounds gage will remain a liquid below 25° F., but will vaporize and become a gas at 25° F. and higher.

d. Ton of refrigeration.—(1) The British termal unit is rather small for large systems. Since the first refrigerating systems were comparatively large and were used almost entirely for the making of artificial ice, another unit was introduced that was particularly applicable to these big ice-making systems. A system that was capable of producing 1 ton of ice in 24 hours was known as "1-ton system." It requires 144 Btu of heat-extracting ability to freeze 1 pound of water at 32° F. to ice at 32° F. Consequently, in order to freeze a ton of ice, 2,000×144, or 288,000 Btu would be required. If this capacity is spread over 24 hours, the capacity of such a machine would be 288,000÷24, or 12,000 Btu per hour. The capacity changes some-

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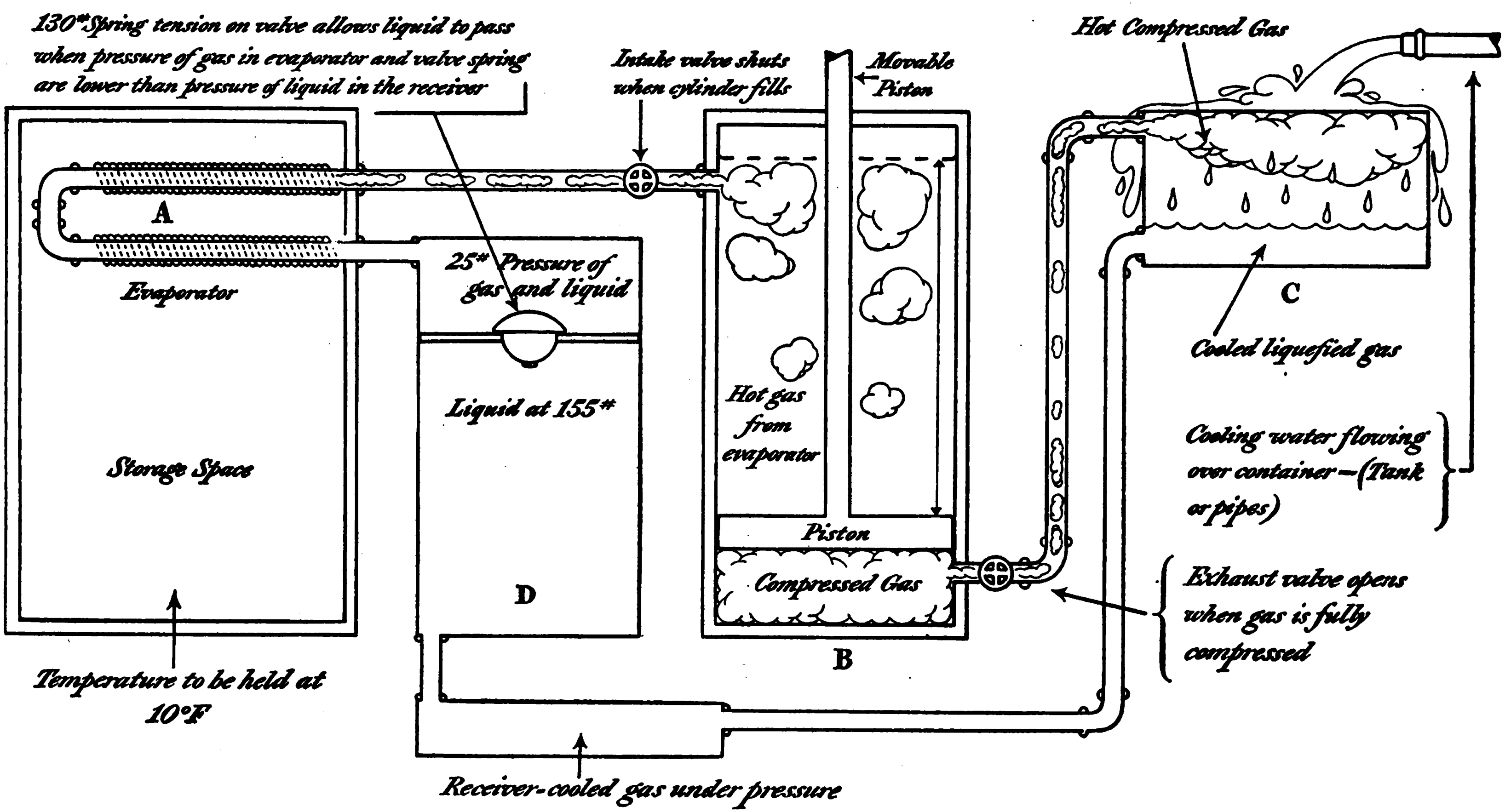

FIGURE 12.—Graphic illustration of vapor compression cycle.

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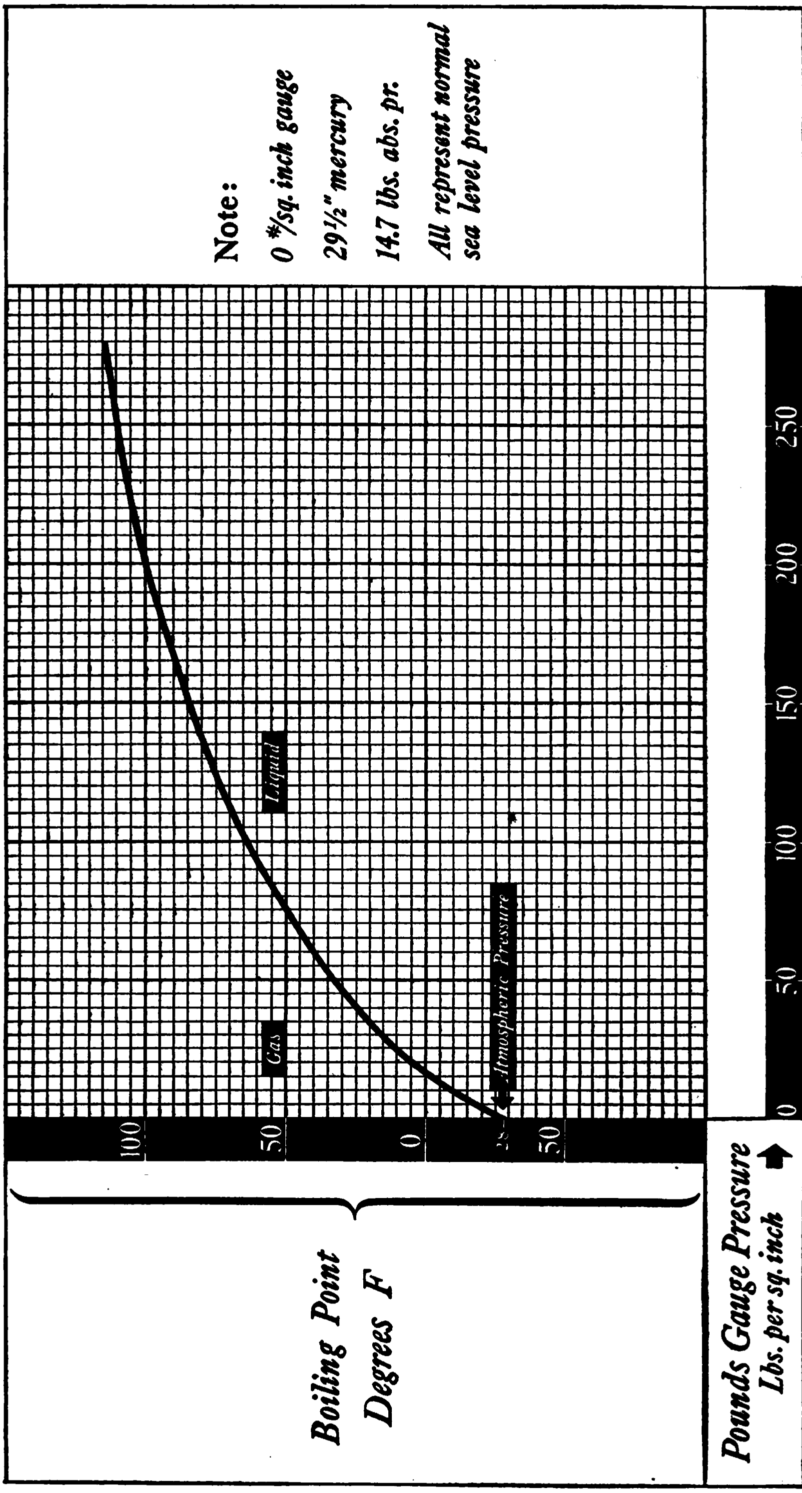

FIGURE 18.—Ammonia pressure vs. temperature.

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what with the operating conditions. Therefore, in order to have a basis for comparing different machines with each other, conditions under which the standard ton of refrigeration should be measured have been defined as follows:

(*a*) *Inlet pressure*.—Suction or back pressure corresponding to an evaporator gas temperature of 5° F.

(*b*) *Outlet pressure*.—A discharge or head pressure, corresponding to a condensing gas temperature of 86° F.

(2) In addition, the definition also specifies the number of degrees of super-heat that the gas should have when it enters the condensing unit, and the number of degrees of subcooling that the liquid should have when it leaves the condensing unit. However, for our purpose, we may think of a standard ton of refrigeration as simply the refrigerating capacity of 12,000 Btu per hour.

10. Insulation.—*a. Principles.*—(1) There would be little practical value in removing heat from a body if the rapid flow of heat back into it could not be prevented. Efficient insulation is as important to the overall economy of a refrigerating plant as efficient heat removal. The walls of storage spaces should be constructed in such a manner as to prevent the transfer of heat from outside sources. Pipes carrying brine or other refrigerants should be coveed to keep these cooling elements from absorbing heat before they reach the area or substance to be refrigerated. Various substances which make good insulators are available. Most of the insulators in use owe their value to the fact that they contain an infinite number of tiny air cells. Air is a poor conductor, and its circulation is reduced to a minimum by the smallness of each air cell. Air must be confined in very small cells to be effective as an insulator; for when it is confined merely between two walls where convection currents may be set up, it has comparatively little insulating value. Should moisture from the air find its way into the air cells and freeze there, the insulation value is reduced because the poor conductor, air, is replaced by a solid ice, having better conductivity. Expansion in process of freezing collapses adjoining cells, and disintegration of the insulation progressively results. For this reason, insulation should be well protected against the infiltration of moisture.

(2) Of whatever material the insulation is made, its value is largely governed by the method of installation. Sheet and board material should be applied in two or more layers with staggered joints, and tightly cemented together and to the walls, ceiling or floor. The outer surfaces should always be vapor-proofed, cement plaster or sheathing being the usual finishing material on the interior. The tightness of doors and other openings in cold storage rooms is a big

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factor in the efficiency of the plant. The thickness of insulation used depends upon the operating temperatures, the exposure of the walls and ceiling to external heat, and the difference between the air outside the compartment and that inside (heat head).

b. Materials used for insulation.—(1) Very few materials meet all the requirements of an ideal insulator for refrigeration purposes. Those in common use are sawdust and shavings, pumice, animal wool (in the form of hair felt), mineral and rock wool, waterproof paper, metal foil sheets, redwood bark, kapok, rock cork, vegetable cork in granulated and board form, etc. In stationary cold-storage plants such materials are used in conjunction with thick walls of brick, hollow tile, dead-air space, etc. In walls, a dead-air space large enough to allow circulation of air was at one time considered a highly efficient and cheap form of insulation; but this method has now been entirely discarded. Hair felt was used extensively in refrigerator car construction and in household refrigerators, and is widely used for pipe covering in industrial plants. Hair felt, mineral wool, rock wool, shavings, and pumice have an affinity for moisture and become conductors when wet. Aluminum foil and many patented materials are used to insulate truck bodies. But practically every insulating material now used incloses air in cavities small enough to prevent any circulation. This gives lightness to the material, a factor that is of prime importance particularly in insulation of transportation equipment.

(2) Hair felt is made almost wholly from cattle hair from tanneries and is felted into blankets from 1 to 2 inches thick.

(3) Mineral wool is made from the slag of blast furnaces with limestone added. The crushed rock is mixed with coke and fed into furnaces at a temperature of about 3,000° F. As the molten slag runs from the furnace, it is blown by high-pressure steam into a fleecelike, fluffy, though brittle mass.

(4) Rock cotton, or rock wool, is made as in (3) above, except that granite and limestone are used. From 92 to 96 percent of the bulk of the finished wool consists of tiny air spaces. The wool is made into slabs about 1 or 2 inches thick.

(5) Vegetable cork is the most efficient and most commonly used insulating material for permanent installations. It is commonly used in the form of slabs, of 1-, 2-, or 3-inch thicknessses, and of varying width and length. It is prepared by cementing cork granules together under pressure by baking or by the use of cement. In this form, if properly installed, it more nearly meets all the requirements of a perfect insulating material than any other form of construction. It

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is light in weight, is a nonconductor of heat, and resists the action of fire and moisture.

(6) The relative values of various insulating or nonheat-conducting materials (dry material, in thicknesses of 1 inch, 1 square foot of surface with a 1° differential), are listed herewith, the rating being in Btu per hour, and the various insulating materials are installed in thicknesses as follows:

Material	*Btu*
Cork sheets, pure	.270
Hair felt	.264
Cork sheets, asphalt cemented	.300
Air space	1.10
Rock wool	.280
Asbestos pressed sheets	.84
Pine, white	.78
Oak, red	1.03
Pine, yellow	1.00
Brick wall	5.00
Sawdust	.41
Gypsum	.60

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CHAPTER 2

MECHANICAL REFRIGERATION SYSTEMS

SECTION I

GENERAL

11. General.—In cold-storage and ice-making plants either the compression or the absorption machine may be installed. In some cases, both are used, the compression type for work requiring higher temperatures, and the absorption type for lower. The compression system is more extensively used because it requires less floor space.

SECTION II

ABSORPTION SYSTEM

12. Principle.—Water readily absorbs ammonia gas, forming aqua ammonia. This property is fundamental in the absorption system and gives it its name. Water and ammonia vaporize at different temperatures. Consequently, if heat is applied to aqua ammonia, the ammonia gas (which boils at a low temperature) will break away from the water. When the water in the system is saturated with the gas, it is called "strong liquor." After the solution has been heated and the gas driven off into the system, the remaining solution is called "weak liquor." The weak liquor is then carried to an absorber, where the ammonia gas, after being used in the evaporator, is returned to the water. This process creates a strong aqua ammonia or strong liquor.

13. Apparatus.—A number of different parts are necessary for the distillation and absorption of ammonia gas in the absorption machine because the expanded ammonia must be returned to the liquid state at high pressure for reuse. The more important parts, exclusive of various valves, gages, pipes and fittings, are as follows:

a. Generator.
b. Analyzer.
c. Rectifier.

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d. Condenser.
e. Receiver.
f. Evaporator.
g. Absorber.
h. Pump.
i. Exchanger.

14. Operation.—*a. Analyzer.*—As the vapor rises through the analyzer, B, it passes through and over a series of baffles. There it meets and mixes with a strong ammonia solution which has been pumped into the analyzer from the exchanger, I. This strong aqua ammonia solution trickles down over the baffles in the analyzer and cools the ammonia gas ascending from the generator. The water vapor condenses and falls down again into the generator, while the now stronger ammonia gas passes on to the rectifier.

b. Rectifier.—While the generator's heating coils are evaporating the ammonia gas, which then rises through the analyzer, most of the water in the vapor will be condensed out. But in order that only dry ammonia gas will enter the condenser, the gas leaving the analyzer must pass over the cooling coils in a chamber called a "rectifier, C." Here the small amount of water remaining is condensed out and the gas passes on to the condenser. The condensate flows from the separator, C1, back to the analyzer.

c. Condenser.—After passing from the generator through the analyzer and rectifier, the hot dry gas goes into a chamber called the "condenser, D." This contains coils through which cold water is running. As the hot gas strikes the cold coils, it condenses to liquid ammonia and passes from the condenser in a tank, E, called the "receiver."

d. Receiver.—The liquid ammonia from the condenser is stored in a tank, which is usually set up at the base of the condenser so that the liquid can run from the condenser by gravity, even though the system is constantly under pressure. From the receiver, the liquid ammonia is released to the evaporator by means of an expansion valve.

e. Evaporator.—In all systems employing the expansion of gas as a refrigerant, the evaporator, F, is the means of conveying the refrigerant to the point at which it will do its work. The evaporator also places the refrigerant in contact with a carrier or secondary refrigerant which has been piped to the area or point, and which after performing its function, returns to the evaporator to release its absorbed heat load. The absorption and vapor compression systems are alike in the principle and operation of the evaporator. As the ammonia liquid from the receiver enters the evaporator, it will absorb its latent heat of vaporization and flow on as a gas to the absorber, G,

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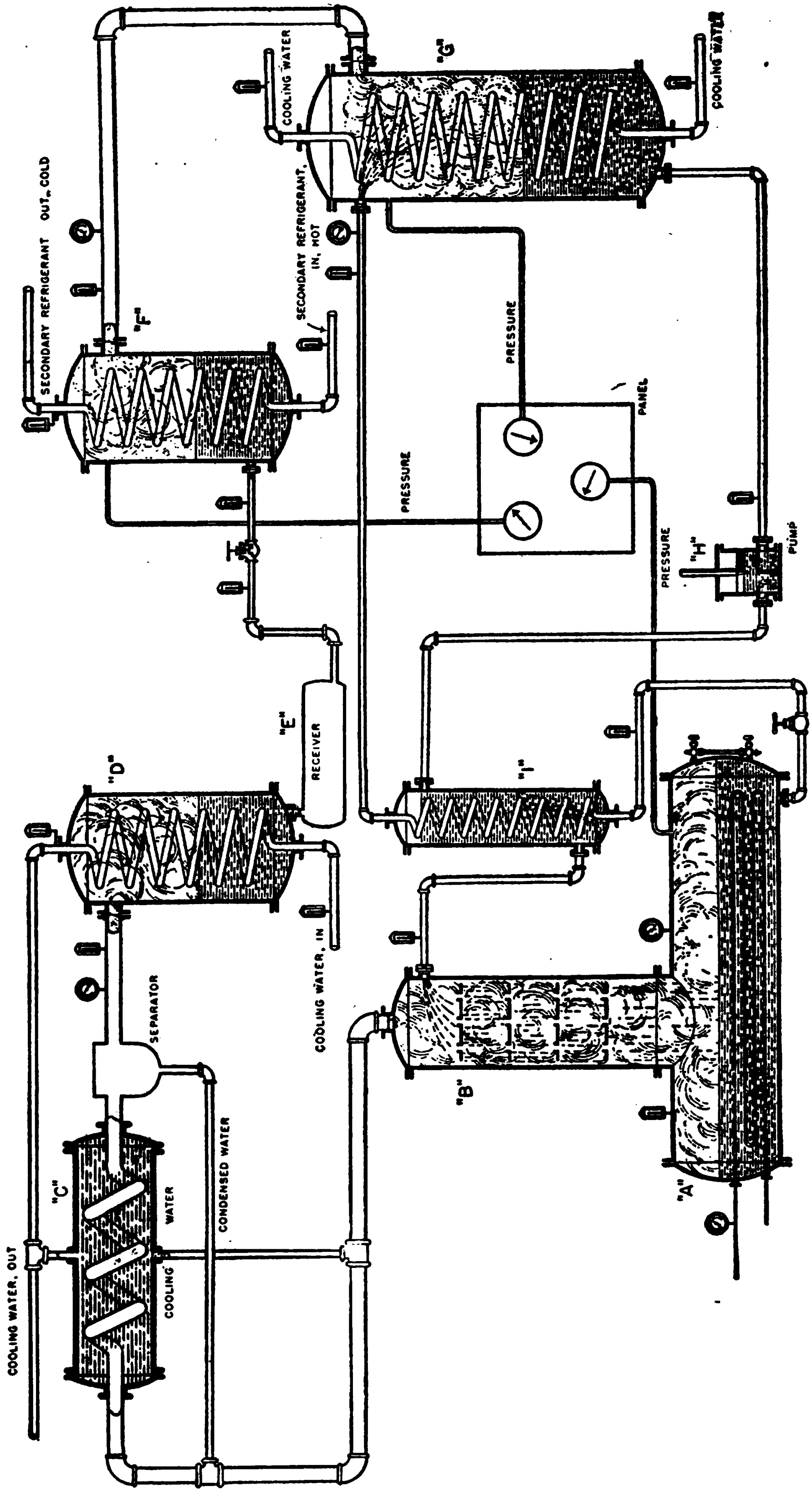

FIGURE 14.—Plan of ammonia absorption system.

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where it is brought into contact with a weak aqua ammonia solution and is absorbed, creating a strong liquor.

f. Absorber.—The gas flowing in from the evaporator comes in contact with a weak ammonia solution passing from the generator through the exchanger, and together they fall over cooling coils in the absorber, where the ammonia gas is absorbed by the weak solution which then becomes a strong aqua solution. This strong solution is now pumped through the exchanger, I, to the analyzer.

g. Exchanger.—The cool, strong aqua ammonia being pumped from the absorber is carried to a cylinder enclosing heat exchanging coils. There it is warmed before entering the analyzer and resuming its cycle. The warm or hot weak ammonia solution moves through the coils in the exchanger, passes off its heat to the strong liquid, and flows into the absorber to contact the warm strong gas from the evaporator there becoming strong liquor.

h. Gages.—A panel is usually installed and is provided with pressure gages to indicate the ammonia pressure in the generator, absorber and cooler. There is also a gage to show the pressure of the stem in the generator. Each gage should have a valve in the line that connects it with the apparatus. A liquid level gage should be placed on the generator, condenser, cooler, absorber, and liquid ammonia receiver.

Section III

VAPOR COMPRESSION SYSTEM

15. Principle.—As explained in paragraph 9*c*(4), the vapor compression cycle includes the compression and condensing of certain gases, which in evaporating, absorb heat from an area or substance and in turn give up that heat when cooled and condensed. There are four essential or basic parts of the vapor compression system; evaporator, compressor, condenser, and expansion valve. This does not include the various other valves, gages, pipes, and fittings.

16. Equipment and functions.—*a.* The evaporator, where the liquid refrigerant is permitted to expand and evaporate under control and to absorb heat from an area, substance, or secondary refrigerant, may be of several different types of construction, and practically all small units and some of the more recently designed larger units are operated automatically. Some of the older type small units and practically all the heavier type evaporators, such as would be found in an

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ice plant, are manually controlled. This control, whether manual or automatic, is largely the manipulation of the liquid refrigerant flow control device to maintain a flow of liquid refrigerant sufficient to meet refrigerating demands. Other operation details for evaporators involve certainty that the flow of air, brine, water, or whatever is to be cooled, is sufficient to produce the desired amount of heat transfer into the liquid refrigerant. Evaporators may be a simple bank of pipes, or pipes fitted with fins to spread the cooling area; it may be of the radiator core type or coils of pipe, through which the refrigerant can flow as freely as a gas. In figure 15 is shown the bank-of-pipes, type A, supplied by a refrigerant entering the evaporator through the expansion valve, B. The expansion valve is set in a pipe line leading up from the receiver. In the drawing, these pipes were drawn small to denote that this was the high pressure side of the system. The pipes drawn large show the low pressure side of the system. The gateway between the high pressure liquid refrigerant and the low pressure refrigerant gas is called the "expansion valve."

b. The expansion valve, B, is a constriction, or regulating device, in the high pressure line. It allows only enough liquid refrigerant to flow through to equal that boiled off in the evaporator. Since the liquid under high pressure in the high side of the system is permitted to enter the evaporator, it is controlled either manually or by some automatic device such as an adjustable valve spring, which may be set to maintain a desired pressure in the evaporator. As the liquid enters the evaporator, it expands and its pressure drops. When the pressure drops, the boiling point is lowered. At the lower boiling point, the latent heat of vaporization is absorbed and the resulting gas is ready to be pumped over for reclamation. In passing through the expansion valve from the high pressure to the lower pressure within the evaporator, a certain amount of heat must be removed to cool the liquid refrigerant. Thus temperature of the liquid is reduced to the lower boiling temperature corresponding to the pressure maintained in the evaporator. This drop in liquid temperature is accomplished by boiling off part of the refrigerant liquid by flash cooling at a point just beyond the expansion valve in the evaporator coils. "Flash cooling" is the term applied to the action of the refrigerant in cooling itself (by using up some of its latent heat-absorption power) to the temperature at which it can exist as a liquid under the pressure in the evaporator. As the liquid refrigerant absorbs heat units and boils itself into a gas, it is drawn out of the evaporator by the pumping action of the compressor. To permit isolation of parts of the system and to facilitate certain maintenance jobs, a stop valve, C, is placed

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in the low pressure suction line close to the evaporator. In this line leading from the evaporator is placed a scale trap, D, whose purpose is to protect the compressor from any grit or scale that may be carried over from the coils. This low pressure line leads to the valve system at the compressor, E.

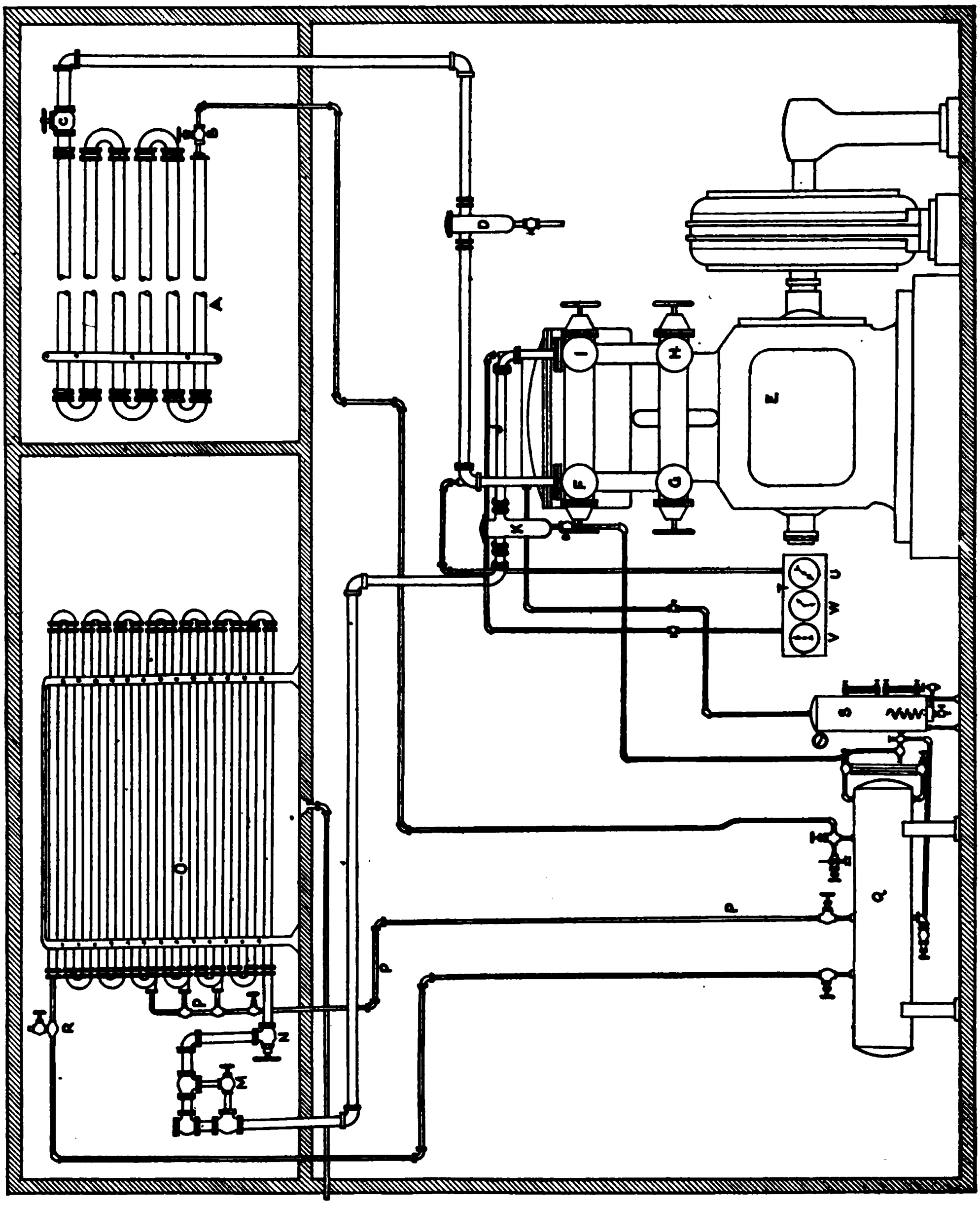

FIGURE 15.—Plan of ammonia vapor compression system.

c. The compressor performs two functions, the most important of which is to withdraw the refrigerant gas from the evaporator and deliver it to the condenser at a sufficiently high pressure so that its latent heat can be absorbed by the condenser cooling medium (water or air) contacting the condensing surfaces at tem-

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peratures that are ordinarily available. By compressing the vapor, the compressor produces a condition of temperature and pressure within the gas, which, upon delivery to the condenser, readily liquefies at temperatures of air or water available. The refrigerant gas drawn from the evaporator has absorbed its full potential heat capacity. It cannot absorb more latent heat until the heat already absorbed has been removed and carried away from the system and the gas changed back to a liquid. Water or air is the usual cooling medium by which the heat absorbed by the refrigerant is carried away from the system. The water or air is available usually at temperatures between 40° F. and 100° F. In order that the water or air at these temperatures can serve to condense the refrigerant again, the pressure of the refrigerant gas must be raised to a pressure at which its condensing temperature is higher than the temperature of the cooling water or air. The pressure to which the gas must be compressed depends on the temperature of the available cooling water or air into which the heat must flow, and on the capacity of the condenser to transfer heat from the gas to the cooling medium. Therefore, the compressor must elevate the pressure of the refrigerant gas to a point somewhat higher than the pressure corresponding to a refrigerant condensing temperature equal to the pressure of the condenser cooling medium (water or air). To illustrate, if the cooling medium were water at a temperature at 70° F., a pressure greater than 114.1 pounds gage would have to be maintained in order to create a differential that would enable the water 70° F. to absorb the heat from the ammonia gas and condense it. If the pressure on the gas was 150 pounds gage, the temperature of the gas would be 84.4° F. (See fig. 13.) The water, being 14.4° F. cooler, will absorb the excess heat and cause the gas to liquefy and pass on to the receiver to be stored for use. This is just one of many different types of compression systems, but it is a standard system, and all compression systems are basically the same. In general, refrigerating compressors are of the reciprocating vertical, single-acting, or horizontal double-acting type driven by electric motor, gasoline, or steam engines. Double-acting compressors are frequently employed for carbon dioxide or larger ammonia systems. Rotary compressors are in use for plants employing ethyl chloride, freon, methyl chloride, etc., as refrigerants. Whether or not cylinder water jackets are provided depends largely on the type of refrigerant used. As the refrigerant gas comes to the compressor and before it can enter for the compression cycle, it must pass through a series of valves so constructed that by opening and closing certain of these the compressor can be used as a

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pump in filling the system with refrigerant pressure testings, or blowing the lines clear for cleaning. The first valve, F, remains closed while the system is in operation. The gas moves past the stem and enters the compressor through the stop-valve, G. The piston in the compressor then compresses the gas which flows out of the compression chamber through the discharge valve, H, and then around the stem of the closed bypass valve, I, into the discharge pipe, J. The discharge pipe carries the compressed gas to the condenser, passing first through an oil trap, K, where the oil is separated from the ammonia gas and piped to a purifier, S, which recovers any ammonia that may have been assimilated by the oil. From the oil trap, the gas may pass to a check-valve, L, which should be set to a pressure that will maintain a steady flow of the gas into the condenser. Around the check-valve is built a bypass in which a valve, M, is installed to permit the gas to be pumped from the condenser. Just before the gas enters the condenser there is a shut-off valve, N, that may be used to cut off the condenser. The compressor, in producing the pressures necessary for condensing the refrigerant gas, performs its second function, that of creating the pressure differential necessary to produce a satisfactory flow of the refrigerant through to the expansion valve.

d. The cendenser, O, is a unit the function of which is to remove superheat, latent heat of vaporization, and in some cases, sensible heat from the refrigerant that has been compressed and delivered to it. The compressor gas passes into the condenser where, owing to the temperature differences between the refrigerant gas and the cooling medium, heat from the gas passes through the metal walls of the condenser tubes into the cooling medium flowing past the surface. Upon entering the condenser, the refrigerant cools to the temperature corresponding to its condensing temperature at the pressure existing in the condenser. This process produces a liquid refrigerant available for future use in the cycle. The condensed refrigerant falls by gravity to a receiver usually placed below the condenser. Condensers rarely require any manipulation by personnel other than that needed to be certain that the flow of cooling medium (water or air) over or through the condenser is sufficient for the load imposed upon the compressor. Large condensers are generally designed to use water as a cooling medium, although air at normal atmospheric temperature will also make a very satisfactory cooling medium for smaller installations. In some cases different types of condensers are used. The evaporative type condenser acts as a simple water-cooled condenser in which the refrigerant is circulated through the tubes while the water is sprayed upon the outside. The

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evaporative type simultaneously cools the air by forcing it up through the spray of water, thus producing better condensing conditions. Evaporative type condensers are preferred because their recirculation of water effects an economy and because a large amount of condensing effect can be installed in a minimum of floor space. Other installations as the shell-and-tube, and multipass condensers are used in cooling brines for ice making. Care must be taken to see that in liquid-cooled condensers of the double pipe type that the water will flow in the opposite direction to the flow of the liquid refrigerant. The liquid ammonia leaves the condenser through a small pipe, P, and flows to the liquid receiver, Q. From the top of the condenser there is also a pipe (usually referred to as an "equalizer line") leading to the receiver for the purpose of maintaining the same pressure in both the liquid receiver and the condenser. In this line there is installed a blow-off valve, R. This valve, sometimes called a "purge valve," is used for the purpose of blowing off noncondensable foreign gases which may reduce the efficiency of the system. It is placed at the top of the condenser, the highest point in the equalizing line from the condenser to the receiver.

e. The receiver, Q, whether integral with or separate from the condenser, acts as a surge reservoir to supply needed refrigerant or to accumulate excess refrigerant. The usual method is the use of the separate tank as shown in figure 15. The liquid receiver is provided with a gage glass so that the quantity of liquid refrigerant may be readily observed, and is connected by a pipe to a purifier, S, which is used to remove foreign substances from the ammonia.

f. The purifier, S, contains a stem coil which boils the ammonia. The resultant ammonia gas is pure when drawn off into the compressor through a pipe connecting to the main suction line above the valve, F. Some other source of heat, such as a hot water coil, is often substituted for this steam coil. A pipe containing ammonia leads down from the oil trap to the purifier and the oil. The ammonia, which has been pumped out of the compressor, is subjected to the heating of the coils in the purifier. When the ammonia boils off, the oil falls to the bottom of the purifier. The purifier is equipped with two separate gage-glasses, one above the other. The lower one shows the level of the impurities in the purifier, and the upper shows the level of the liquid ammonia. Draining of the oil trap to the purifier, draining of impurities from the purifier, and the releasing of liquid ammonia to be sucked into the compressor are activities which are usually manually controlled.

g. An instrument board, T, carries a low pressure gage, U, connected to the suction line by a pipe, and a high pressure gage, V,

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connected to the compressor discharge line. For purposes of control in varying conditions, additional thermometers and gages are sometimes installed in the system.

17. Operation and maintenance.—*a. General.*—Operation of practically all evaporator compression systems is automatic. Operation consists primarily of inspection of the proper gages to assure efficient operation within the system.

b. Starting.—(1) New and small units are started simply by opening the system, turning on the power and after careful inspection of gages, etc., the machine will function automatically.

(2) Larger installations and older installations however, must follow a certain definite procedure so that the refrigerating machinery is not called upon to accept its full load at once.

c. Maintenance.—(1) Maintenance as discussed herein will be considered only in the light of refueling the system with oil or refrigerant. Maintenance of systems employing ammonia is similar to maintenance of most other systems. Because ammonia systems are, as a rule, larger and of more varied design, periodic routine preventive maintenance operations must be carried on. Maintenance schedules are of the greatest importance.

(2) Oil may be added to ammonia compressors of the inclosed vertical single-acting type by utilization of the suction effect of the oil pump itself. It may also be added by manipulating the valve manifold in such a way as to produce a partial vacuum within the crank case, and then applying this vacuum to a hose or pipe that extends into the container of oil. On horizontal double-acting compressors that have forced-feed lubrication, the suction effect of the pump is utilized as described for the vertical single-acting compressor. A number of horizontal double-acting compressors use gravity oil feed, where the addition of oil involves only the simple procedure of pouring a container of oil into the oil supply tank.

(3) The addition of refrigerant liquid to an ammonia system has become a standardized operation, and the connections used are shown in the diagram below. The liquid added is supplied directly to the liquid supply line of the system between the receiver "king valve" on top of receiver and the expansion valve. The refrigerant cylinder is tilted so that the valve outlet is down. The cylinder is rolled over until the nipple within the cylinder itself points down, thus making certain that only liquid refrigerant will come out. The plant operator must be able to determine when it is necessary to add refrigerant to the system. He must observe carefully the suction pressure gages indicating operating conditions within the evaporator and also the height of liquid appearing in the receiver gage glass. One indication

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of a need for additional refrigerant is a lowering of indicated discharge or head pressure and an increase in the temperature of the liquid line at the expansion valve, which, of course, will melt frost on the expansion valve.

d. Trouble-shooting charts.—The chart in appendix II has been prepared, changed, revised, and edited by a number of manufacturers and men in the field. It is a valuable check for operating conditions and performs ready diagnosis of present or suspected troubles that may require maintenance. Basically, this chart is the same for all refrigerants, and will be referred to constantly.

e. Safety precautions.—(1) Guards should never be removed from the bands or pulley wheels while the machine is in motion, and should be replaced before the equipment is started. This applies even to the smallest pieces of equipment. Insulation material such as rubber mats in front switchboards, rubber gloves for switch operators, insulated fuse pullers, etc., should be periodically scrutinized for their serviceability. Grease spots or oil puddles should never be permitted to remain on floors. Supplies, tools, and equipment should be neatly stacked at all times, for good housekeeping helps make a plant efficient as well as safe. The correct tool for the job should always be used. For example, pipe wrenches should not be used on nuts or bolts because they produce sharp burs which may later cause a cut and an infected hand for someone else. Wrenches (particularly of the open-end type) that have split and do not fit the proper nut or bolt should be immediately discarded. Safety for personnel cannot be overemphasized.

(2) Safety of mechanical and electrical equipment is adequately provided for by the manufacturer or by installation specification requirements. These safety devices, among which are the previously mentioned pressure-relief valve, fusible plugs, overload release devices, fuses, overcurrent release, temperature release, etc., are often subjected to such mistreatment as to render them useless. A safety device that fails to function is worse than no safety device at all, because the operator, relying upon them for protection, will neglect his equipment.

SECTION IV

DIRECT AND INDIRECT EXPANSION SYSTEMS

18. Direct.—The system just described above is known as the "direct expansion system" because the act of absorption of the heat

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from the enclosure is direct upon that enclosure. The refrigerant is piped directly, and the heat absorption takes place directly through the walls of the pipes, finned tubes, or hollow plates containing the refrigerant. (See fig. 15.) Although direct expansion systems are very efficient, they require relatively larger quantities of refrigerant. This is true especially if the area to be refrigerated is large, or if it is spread out over a considerable distance (such as several storage rooms and ice-making plants).

19. Indirect.—The indirect system permits the refrigerant to act on a secondary refrigerant (air, water, or brine), which in turn can be piped out over the system to carry on its work, after which it returns to the primary refrigerant to give up the heat it has absorbed. Other factors which lead to the employment of the indirect rather than the direct method are that due to breaks in the direct system the escaping refrigerant gas might spoil the products being refrigerated, that the mixture of refrigerant gas and air might create a fire hazard, or the amount of refrigerant released by the break would necessitate a shut-down until repairs were completed. Therefore, most operators have found it more satisfactory to use a secondary medium for larger installations. The mediums used for this purpose are usually calcium chloride or sodium chloride brine.

20. Types of brines.—*a.* Two kinds of brine are used; one is a solution of sodium chloride (common salt) in water, and the other a solution of calcium chloride. Sodium chloride brine is generally used in ice tanks and brine-spray installations; calcium chloride brine is always used where subzero temperatures are produced. The freezing point of brine is lowered in proportion to the density of the brine, up to a certain point. The density at which sodium chloride brine will attain its lowest temperature is at a specific gravity of 1.176, with 22.42 per cent of salt. This brine will freeze at a temperature of $-6.16°$ F.; as the density of the brine increases above this point, the freezing point is raised. In the use of sodium chloride brine, only sufficient density is used to allow a safe margin between the lowest produced temperature and the freezing point of the brine. Too great a density may cause precipitation of salt in the pipes. Likewise, the specific heat of the brine grows less with increasing concentration. Calcium chloride brine can be reduced to a temperature of $-54°$ F., at its optimum density.

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b. A comparison of sodium chloride and calcium chloride brines is made in the table below (from Refrigeration, by Moyer and Fittz):

Sodium chloride			Calcium chloride		
Percent salt by weight	Specific gravity	Freezing point (°F.)	Percent salt by weight	Specific gravity	Freezing point (°F.)
5	1. 036	26. 7	8	1. 069	24. 2
6	1. 044	25. 5	9	1. 078	22. 8
7	1. 051	24. 2	10	1. 087	21. 4
8	1. 058	22. 9	11	1. 096	19. 8
9	1. 066	21. 6	12	1. 105	18. 2
10	1. 073	20. 2	13	1. 114	16. 3
11	1. 081	18. 8	14	1. 124	14. 4
12	1. 088	17. 3	15	1. 133	12. 2
13	1. 096	15. 7	16	1. 143	9. 9
14	1. 104	14. 1	17	1. 152	7. 4
15	1. 112	12. 4	18	1. 162	4. 7
16	1. 119	10. 6	19	1. 172	1. 9
17	1. 127	8. 7	20	1. 182	−1. 0
18	1. 135	6. 7	21	1. 192	−4. 0
19	1. 143	4. 6	22	1. 202	−7. 3
20	1. 151	2. 4	23	1. 212	−10. 6
21	1. 159	0. 0	24	1. 223	−14. 1
22	1. 167	−2. 5	25	1. 233	−18. 0
23	1. 176	−5. 2	26	1. 244	−22. 0
24	1. 184	1. 4	27	1. 254	−27. 0
25	1. 192	13. 3	28	1. 265	32. 0
			29	1. 276	39.
			30	1. 287	−46.

Calcium chloride brine is used where subzero temperatures are required. It is never used in brine-spray systems, because drops of the spray coming in contact with meat or other foods produce whitish spots, due to dehydration, and also impart a bitter flavor. The concentration of the solution use varies with the temperature desired. Usually, the brine density is just sufficient to obtain the desired temperatures without freezing the brine. Brine requires from 50 to 100 percent more heat transfer surface than direct expansion.

21. Methods of cooling brine.—*a*. The brine is cooled by contact with direct-expansion coils in brine tanks, shell coolers, or pipe coolers. The shell cooler is more compact and efficient than a tank and coil system. It consists of a cylindrical metal tank through which runs a number of brine tubes. The ammonia is introduced into the space between the tubes and the shell. The brine to be chilled enters

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the top tubes and is drawn off at the bottom tubes, while the liquid ammonia enters the shell at the bottom and the gas is drawn off at the top, and operates on the same principle as a horizontal fire tube boiler.

b. The double-pipe cooler is frequently used in smaller installations. It is the most efficient form of brine cooler; it occupies little space, and is easily kept in repair. It consists of 2-inch pipes within 3-inch pipes, arranged in stands. The ammonia circulates in the space between the two pipes, while the inner pipes carry the brine. The ammonia enters the bottom coil of the stand and the gas passes out at the top in the same manner as for the shell cooler, while the brine flows in a counter direction. A stand 12 pipes high and 18 feet long is rated at a capacity of 15 tons of refrigeration.

22. Methods of circulating brines.—*a. Brine coils.*—The chilled brine is circulated in the room to be refrigerated. The most common method of circulation is through closed coils so placed on the walls or the ceiling as to cool the room most effectively. The length of brine pipe necessary to refrigerate a room varies with the size of the room, the size of the pipe, and the temperature desired. The smaller the room, the relatively larger amount of piping required. For example, for a room under 1,000 cubic feet capacity, 1 lineal foot of 2-inch pipe will refrigerate 1 cubic foot of space at zero; while in rooms over 10,000 cubic feet capacity, 1 foot of 2-inch pipe will refrigerate 3 or more cubic feet at zero. Again, 1 lineal foot of 1-inch pipe will refrigerate less than half as many cubic feet of space as will 1 foot of 2-inch pipe. While, in rooms of less than 1,000 cubic feet of space, 1 foot of 2-inch pipe is required for each cubic foot of space at zero, the same 1 foot of pipe will refrigerate 4 cubic feet of space at 10° F., 6 cubic feet at 20° F., 8 cubic feet at 32° F., and 10 cubic feet at 36° F. Brine has several advantages over direct expansion ammonia. It is less hazardous, more easily regulated, and more safely used at a distance. It yields a more even temperature, due to its larger volume, and relative humidity is thus more easily controlled.

b. Ammonia coils.—A small refrigerator requires approximately the same number of direct-expansion (ammonia) coils as of brine. But the ratio becomes increasingly smaller as the capacity of the refrigerator increases. At 10,000 cubic feet capacity, 1 foot of 2-inch direct expansion pipe will hold 6 cubic feet of space at zero as against only 3 cubic feet for brine. The length of ammonia coils can be considerably greater than brine coils. Brine loses its efficiency in coils of greater length than 100 feet at zero or 300 feet at 36° F.

c. Sheet brine refrigeration.—Much of the efficiency of any system of refrigeration depends upon the amount of refrigerated surface exposed to the air of the room to be refrigerated. In closed coil systems,

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the amount of exposed refrigerating surface is fixed. In addition, coils soon become coated with frost and ice as a result of freezing moisture from the air, and the refrigerating capacity of the coils is reduced. Many methods have been devised to increase the efficiency of brine by increasing the amount of surface exposed. One of these methods was known as the "sheet" or "curtain" method, and was used quite extensively about 20 years ago by the meat packers in their meat coolers. It consisted of a number of light muslin or cheesecloth sheets suspended on edge beneath shallow troughs and stretching from side to side across a loft above the chill room, about 8 inches apart. Brine flowed continuously into these troughs and trickled down over the suspended sheets. The cold sheets thus presented extensive chilled surfaces to contact the warm air of the rooms, which rose to the loft, chilled the air to a lower temperature, and resulted in drier walls, ceilings, and carcasses because of the precipitation of moisture on the cold sheets. This method, however, has been entirely replaced in packinghouse coolers by the more efficient brine-spray system.

d. Brine-spray system.—(1) In the brine-spray system, the brine is forced through spray nozzles which break it into mistlike particles. The adoption of this system has greatly increased the cooling capacity of coolers because of the greatly increased refrigerating surface represented by the fine particles of mist. This efficiency is conceivable if one imagines a large drop of brine, 1 inch in diameter, having a temperature of 20° F., being thrown into the loft. The area of a 1-inch sphere is 3.1416 square inches. Its refrigerating effect would be very small. Now break this large drop into exceedingly small particles—so small there would be a "mist." Reduce the small particles to one-thousandths of an inch in diameter. The area of each particle would be 0.0000031416 of a square inch. According to mathematics, the 1-inch sphere of water would be broken into 1,000,000,000 particles, each particle one-thousandth of an inch in diameter. Therefore, multiplying 0.0000031416 by 1,000,000,000 we get a total area of 3,141.6 square inches when the 1-inch sphere is broken into the fine particles. In other words, the area becomes 1,000 times greater after the break-up. Or, putting it in a different way, the area of the 1-inch sphere of brine, when atomized, is equivalent to the area of a 1-inch pipe over 80 feet long.

(2) In the brine-spray system, the brine is atomized by forcing it under high pressure through spray nozzles. The brine absorbs heat from the air with which it comes in contact, and also takes up moisture carried to it from the product by the air. The brine flows into a trough and is returned to the brine-cooling equipment. In the brine-spray system, also, humidity can be more accurately controlled. Brine

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spray in lofts is uneconomical because of the head room required. Also, since the spray is located at a distance from the product to be chilled, it must be of lower temperature. New installations are largely within the room to be chilled, within partitions along walls, or between pillars. This increases refrigeration efficiency, since the refrigerant is close to the product to be chilled; it saves space, and it decreases chilling time. Baffles, known as moisture eliminators, prevent the spray from leaving the chamber with the air flow. Properly engineered systems utilize a series of air ducts to distribute the air in order to produce uniform conditions throughout the room. Self-contained unit coolers have become quite popular for this work. These are installed at various points within the room. The refrigerant may be ammonia or any of the refrigerants used in small refrigerating units, and the coils may be operated dry or with a brine spray. Positive circulation of air at any speed desired is obtained by regulating the speed of the fan; the temperature is controlled by the temperature of the refrigerant. Brine-spray units are useful in controlling rooms where damp, humid conditions are encountered. The fan draws air through the ducts from any level desired and discharges it at the desired level. This is the most economical first cost system of refrigeration for chill rooms. The disadvantage of the unit coolers is that high capacity ratings are obtained by lowering the temperature of the refrigerant and increasing the velocity of the air. While this practice is effective in producing rapid heat transfer, the system is injurious to products in storage which are damaged by air movement and low relative humidity.

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CHAPTER 3

ARMY COLD STORAGE AND ICE PLANT OPERATION

23. General.—The following sections present the methods of applying the principles of storage and handling of foods that make up the major portion of the Army garrison ration and the type "A" field ration. In addition, these sections explain the methods of applying the refrigeration principle to the manufacture of ice. Ice-making is not usually a function of the Army in the field, although there are some portable ice-making machines now in use for supplying hospitals and other services requiring ice as well as refrigeration. The description of the ice-making plant contained herein is general and applies to the small unit mentioned as well as to the large refrigeration plants in the base depots.

a. The effective use of cold storage is a very important factor in the preserving of perishables and in maintaining the health and morale of officers and men. Improperly refrigerated foods may become unsuitable for consumption, unattractive in appearance, and unpalatable. Wilting, softening, loss of weight, loss of part of the vitamin content, discoloration, molding, rotting, and souring are some of the types of deterioration which may occur in perishable food materials if they are not properly refrigerated.

b. The spoilage of food materials is brought about principally by the action of the enzymes of bacteria, yeasts, and molds. Enzymes are unorganized or chemical compounds which cause chemical transformation (such as fermentation) without being affected themselves by such changes. This action of the enzymes is called catalysis. The effectiveness of their action is determined by the temperature, intensity of acidity or alkalinity of the amount of moisture present, the nature of the raw material, and other factors. Many enzymes are most active at room or body temperatures. The rate of action is decreased by lowering the temperature, and some enzymes act slowly even at temperatures considerably below the freezing point.

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(1) There are several kinds of enzymes, each usually specific in action. Some break-down protein substances, such as meat, with consequent characteristic putrefaction odors; some attack carbohydrates, such as starches and sugars; some act upon fats and oils, such as those in butter and mayonnaise. Enzymes are secreted by bacteria, yeasts, and molds known as microorganisms. Many plant and animal tissues also contain enzymes, some of which may cause injury unless inactivated by temperature and humidity control.

(2) Various species of bacteria, yeasts, and molds may be found in or on food materials, and when conditions favorable to their growth prevail, rapid spoilage may result. Certain species of bacteria, under optimum conditions, may reproduce in a very short time. With the aid of proper refrigeration, however, reproduction may be greatly slowed down or entirely stopped.

(3) Molds are the principal causes of the spoilage of citrus fruits and apples in storage. Molds reproduce primarily through spore formation. These spores are light in weight and may be very easily carried through the air to contaminate other products. For this reason, proper handling methods and sanitation, as well as the maintaining of proper temperatures, are very important.

24. Army cold storage plants.—The Army cold storage plant usually contains four or more rooms, each designed for a definite purpose: a freezer room for the storage of frozen items, a chill room for the storage of fresh carcass meat or meat products, and so-called "cooler rooms" for dairy and egg products, and for fresh fruits and vegetables which are not highly perishable. There also may be a small refrigerated room for the storage of fresh fish. In the following paragraphs is given a description of the various storage rooms, their operating temperatures, the types of perishables that would normally be stored in these rooms, and the length of time they may be safely stored at the various temperatures. There may be exceptions to the stated length of safe storage periods because of the initial quality of the product, the skill with which the plant is operated, and the design of the equipment. However, the temperatures, service classifications and storage periods listed are considered to be average, under the known circumstances.

25. Operation of freezer storage room (temperature 10° F.).—*a.* The freezer room should be maintained at a temperature of 10° F., plus or minus 2°. All frozen items should be stored in the freezer room.

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(1) A partial list of such items and the length of time they should be kept under these temperatures is given below:

Product	*Maximum storage period*
Butter and cream	3 to 4 months.
Meat and meat products	3 to 4 months.
Poultry, frozen	3 to 4 months.
Fish, frozen, packaged	3 to 4 months.
Eggs, frozen, in cans	3 to 4 months.
Fruits and vegetables, frozen	3 to 4 months.
Fruit juices and pulp, frozen	3 to 4 months.

(2) Frozen fish should be carefully wrapped in clean, odorless packages. Material escaping from improperly packaged fish may contaminate the parts of the room and the handling equipment with which it comes in contact. Subsequently it may give rise to offensive odors.

(3) Where it is desired to carry the above products for a longer period, the storage temperature should be lowered to zero Fahrenheit and maintained at that level. At ports of embarkation or other locations where these products are stored for reshipment, zero Fahrenheit temperature should likewise be provided. Products stored in a zero Fahrenheit room are less likely to suffer ill effects from exposure during loading operations.

b. Solidly frozen products may be arranged in compact stacks.

c. Items received and accepted in a slightly defrosted condition should be refrozen without delay in order to prevent spoilage. Items may be frozen in or out of their containers. Containers of frozen foods should be distributed on the floor with adequate space between the individual packages. Whenever practical, contents should be removed from the containers and distributed in such a manner that they will refreeze rapidly. The use of a portable fan to create a rapid current of air over the products will hasten the rate of refreezing. It is usually unnecessary to take any special precautions with carcass meat, since air spaces will be naturally present even when the product is closely packed.

d. Forced circulation of air in the freezer rooms should be avoided except when items are to be frozen under emergency conditions; otherwise, dehydration and discoloration of products may result.

e. The freezer room should not be used for the purpose of freezing foods (with the exception of the cases outlined above), since the rate of freezing is not sufficiently rapid to be classified as "quick freezing." In general, the quality of slowly frozen goods is not equal to that of quickly frozen goods. The usual type of freezer room used by the Army may be termed a "holding freezer." It differs from the sharp freezers used for the initial freezing of fresh meat, fish, etc., which are operated at temperatures of zero to $-20°$ F. Sharp freezing re-

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quires the carrying away of heat by means of circulated air. Although this type of freezing is rapid, ice crystals are formed in the product frozen. Quick freezing, on the other hand, required sudden exposure of the product to extremely low temperatures. In this process, the freezing is so rapid that there is little formation of water or of ice crystals. The product is frozen solid, but because its cellular structure does not have time to break down, the product can be restored to its original state without loss of form, palatability, and food value.

26. Operation of chill room (at 32° F.).—*a.* The chill room should be maintained at a temperature of 32° F., plus or minus 2°. The temperature should not be permitted to go below 30° F., because the slow freezing of meat will cause discoloration of the surface.

Product	*Maximum storage period*
Beef and beef cuts, fresh	7 to 9 days.
Pork and pork cuts, fresh	3 to 4 days.
Pork sausage	2 to 3 days.
Bacon, smoked, mild cured	2 to 3 weeks.
Ham, smoked, mild cured	2 to 3 weeks.
Cold cuts, cooked delicatessen meats	6 to 7 days.
Salami, dry	10 to 14 days.
Bologna	6 to 7 days.

When any of the above products is to be stored longer than the maximum periods shown, it should be properly frozen and carried in freezer storage at 10° F. or 0° F. Salt pork and heavy cured bacon and ham may be carried at 30° to 32° F. for 2 to 3 months without appreciable loss of quality. Fresh pork and pork sausage are stored best at a temperature of 26° to 28° F. However, it is not practical to provide a special room for this purpose. Therefore, such products should be placed in the coldest part of the chill room, and the storage period should be limited as shown above.

b. Air movement in the chill room should be sufficient only to maintain a uniform temperature throughout the room. Air traveling at a high rate of speed and coming in contact with the stored product may cause damage to the product.

27. Operation of cooler rooms (at 35° F.).—*a.* The cooler rooms should be maintained at a temperature of 35° F., plus or minus 2°.

b. There should be at least two cooler rooms, one for the storage of dairy products, eggs, and lard or lard substitutes, and one for fresh fruits and vegetables. An additional room should be provided if fresh fish is to be stored.

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c. The velocity of the refrigerated air should be just sufficient to maintain a uniform temperature in the rooms, since higher velocities may cause undue dehydration and injury to the products.

d. The following products should be placed in the cooler rooms:

(1) *Eggs and dairy products room (at 35° F.).*

Product	*Maximum storage period*
Buttermilk	36 hours.
Butter	20 days.
Cheese, Domestic Cheddar or Processed	3 to 4 months.
Cream	8 to 10 days.
Eggs, in shell	2 to 3 weeks.
Eggs, dried, powder	2 to 3 months.
Lard, and lard substitutes	5 to 6 months.
Milk, fluid, fresh	36 hours.
Milk, dried, powder	2 to 3 months.
Yeast, compressed, packaged	8 to 10 days.

NOTE.—Lowering the storage temperature to 32° F. and maintaining constant temperature and ideal humidity and air motion conditions will make possible a somewhat longer storage period for all of the preceding products except buttermilk, butter, cream, milk, and yeast. Butter and cream may be frozen and carried for 3 to 4 months in freezer storage at 10° F.

(2) *Fresh fruits and vegetables room (at 35° F.).*

Product	*Maximum storage period*
Apples	2 to 3 months.
Artichokes	1 to 2 weeks.
Asparagus	7 to 10 days.
Beans, green or wax, snap	7 to 10 days.
Beans, green limas	7 to 10 days.
Beets, small with tops	7 to 10 days.
Broccoli	7 to 10 days.
Brussels sprouts	7 to 10 days.
Cabbage, native or Chinese	1 to 2 weeks.
Carrots, small with tops	7 to 10 days.
Cauliflower	7 to 10 days.
Celery	1 to 2 weeks.
Corn, green	7 to 10 days.
Endives	7 to 10 days.
Lettuce	7 to 10 days.
Okra	7 to 10 days.
Peas, green, pod	7 to 10 days.
Peppers, bell and fresh pod	1 to 2 weeks.

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Product	Maximum storage period
Radishes	7 to 10 days.
Spinach	7 to 10 days.
Squash, summer	7 to 10 days.
Turnips, small, tops on	7 to 10 days.
Apricots	1 to 2 weeks.
Berries, all varieties	5 to 7 days.
Cherries	7 to 10 days.
Currants, fresh	5 to 7 days.
Cranberries	2 to 3 weeks.
Figs, fresh	5 to 7 days.
Grapes, all varieties	2 to 3 weeks.
Nectarines	1 to 2 weeks.
Peaches	1 to 2 weeks.
Pears, Bartlett, colored	5 to 7 days.
Pears, Bartlett, green	1 to 2 weeks.
Plums, all varieties	7 to 10 days.
Watermelons, for chilling	1 to 2 days.

NOTE.—The above storage periods are based upon the assumption that products have been received promptly in suitable condition from the field or orchard. Any delay occasioned by transportation or other means, or any overmaturity will shorten the life of the product. A slightly longer storage period may be had by lowering the temperature to 32° F. and maintaining constant temperature and ideal humidity and air motion.

(3) Lard and its substitutes may be placed in ventilated storage for short periods of time if the temperature is kept below 65° F. These products may be refrigerated either in the chill room for meat or in the cooler room for dairy products. They should be placed in a confined space with fruits and vegetables.

28. Operation of ventilated storage room (at 50° to 60° F.).—*a.* The ventilated storage room should be maintained at a temperature of 60° F., if possible. When refrigeration is available, it will not be difficult to hold the temperature at 60° F. But when no refrigeration is available, the room should be ventilated during the cool hours of night and kept closed as much as possible during the day. In winter, it may be necessary to heat the room to prevent the temperature from going below 32° F.

b. The room should be provided with an efficient ventilating system.

c. The items stored in ventilated storage rooms should not be highly perishable but should be products which can be stored satisfactorily for several days to 2 or 3 weeks at the prevalent temperatures.

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(1) The following items may be stored in the ventilated storage rooms:

Product	*Maximum storage period*
Apples	1 to 2 weeks.
Avocados	5 to 7 days.
Bananas (depending upon condition)	5 to 10 days.
Beets, large, mature, tops off	7 to 10 days.
Casabas	5 to 7 days.
Citrus fruits, all varieties	1 to 2 weeks.
Cucumbers	5 to 7 days.
Dates, fresh	7 to 10 days.
Eggplant	5 to 7 days.
Dried fruits, all varieties	3 to 4 weeks.
Garlic	2 to 3 weeks.
Melons, honeydew, cantaloupe	5 to 7 days.
Onions	2 to 3 weeks.
Parsnips	7 to 10 days.
Pears, green, winter varieties	1 to 2 weeks.
Peppers, cured, pod	3 to 4 weeks.
Potatoes, white and sweet	3 to 4 weeks.
Pumpkins	3 to 4 weeks.
Rutabagas	7 to 10 days.
Squash, Hubbard	3 to 4 weeks.
Tomatoes	5 to 7 days.
Turnips, large, matured, tops off	7 to 10 days.
Lard and lard substitutes	3 to 4 weeks.
Fish, dried, smoked or salted	1 to 2 weeks.
Glucose, syrups	3 to 4 weeks.
Honey	3 to 4 weeks.
Meat, canned	2 to 3 months.
Milk, evaporated, canned	2 to 3 months.
Molasses	2 to 3 months.
Nuts	2 to 3 months.
Oil, cooking	2 to 3 months.
Pickles	2 to 3 months.
Syrups	2 to 3 months.

Following is a list of these same products grouped under the minimum storage temperature permissible without possible damage:

(2) *Storage at 32° F.*

Apples (depending upon variety, etc.)	2 to 8 months.
Beets, large, mature, tops off	3 to 4 weeks.
Dates, fresh	3 to 4 weeks.

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Product	*Maximum storage period*
Garlic (depending upon condition)	3 to 4 months.
Onions (depending upon variety)	2 to 6 months.
Parsnips	3 to 4 weeks.
Pears, green, winter varieties	6 to 8 weeks.
Peppers, cured, pod	2 to 3 months.
Rutabagas	6 to 8 weeks.
Turnips, large, mature, tops off	3 to 4 weeks.
Fish, dried, smoked or salted	3 to 4 months.
Glucose, syrups	3 to 4 months.
Nuts	3 to 4 months.
Pickles	4 to 6 months.

(3) *Storage at 38° to 40° F.*

Avocados	1 to 2 weeks.
Casabas	2 to 3 weeks.
Citrus fruits, all varieties	6 to 8 weeks.
Cucumbers	7 to 10 days.
Eggplant	7 to 10 days.
Dried fruits, all varieties	3 to 4 months.
Melons, honeydew, cantaloupe	7 to 10 days.
Potatoes, sweet	2 to 3 months.
Potatoes, white (depending on variety)	3 to 4 months.
Pumpkins	2 to 3 months.
Squash, Hubbard	2 to 3 months.
Tomatoes	7 to 10 days.
Lard and lard substitutes	3 to 4 months.
Honey	2 to 3 months.
Meat, canned	5 to 6 months.
Milk, evaporated, canned	5 to 6 months.
Molasses	3 to 4 months.
Oil, cooking	3 to 4 months.
Syrups	3 to 4 months.

(4) *Storage at 50° to 60° F.*

Bananas (depending upon condition)	5 to 10 days.

NOTE.—The above storage periods are based upon the assumption that the products have been received in a fresh condition. For normal distribution at cantonments within the United States, the ventilated storage at 50° to 60° F. will be suitable for all products as shown.

(5) *Ventilated storage.*—(*a*) Apples may be stored quite satisfactorily in the ventilated storage room, since they are naturally a hardy fruit with good keeping qualities. Most varieties may be stored suc-

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cessfully for several weeks without the use of refrigeration, although there are certain early varieties which do not keep well. If the apples have been received from a refrigerated warehouse, it may be wise to continue to keep them in cold storage unless they are to be consumed shortly. Apples which have been in unrefrigerated storage for several months may be approaching the end of their normal storage period. If not refrigerated, they may rot rather quickly.

(*b*) Citrus fruits may be placed in ventilated storage. But if the fruit received has previously been kept under refrigeration, it should be continued under refrigeration in the fruit and vegetable room. In general, however, storage temperatures below 40° F. should be avoided, since they are likely to injure the fruit. Citrus fruits should not be stored in the dairy room or with meat. Since molds are the chief causes of the destruction of citrus fruits, decayed fruit should not be allowed to remain in the storage room.

(*c*) Cucumbers, eggplants, and tomatoes may be injured by temperatures below 40° F. It is therefore advisable to store them in a cool ventilated location. Should these products be received fully ripe, they may be placed in the fruit and vegetable cooler for a short holding period at 35° F.

(*d*) Dried fruits, such as prunes, peaches, raisins, apricots, pears, and apples do not require refrigeration unless they are to be stored for long periods of time. Dried fruits, however, may be stored in any of the cooler rooms to protect them from insect infestation.

(*e*) Pears of the winter varieties, unless ripe when purchased, may be successfully stored in the ventilated storage room for 2 or more weeks. Bartlett pears are more perishable than winter varieties such as Hardy, Comice, Bosc, and Winter Melis. After Bartlett pears have commenced to turn yellow, they should be stored under refrigeration; but if they are green when received, they can usually be stored satisfactorily from 6 to 8 days at ordinary room temperatures.

(*f*) Cured fish does not ordinarily require refrigeration. If it is to be stored for several weeks, it may be placed in the fish cooler.

(*g*) Canned meats, with the exception of canned ham and luncheon meat, may be placed in ventilated storage. Canned ham or luncheon meat may be refrigerated in any one of the cooler rooms.

29. Safety precautions.—*a*. Wherever temperatures below freezing are maintained, an alarm signal which can be operated from a location within the room should be installed. A long-handled ax should be hung in a suitable place near the exit door for use by any person accidently locked in the room.

b. All small meathooks which are not being used should be turned

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inward in the brackets to prevent injury to workmen. If these hooks are never used, they should be boxed up and stored.

c. All meat trolleys which are not actually being used should be placed out of the way of workmen. If the trolleys are never used, they should be properly packed and stored. Not only do they constitute a safety hazard when scattered throughout a plant, but they also take up valuable storage space.

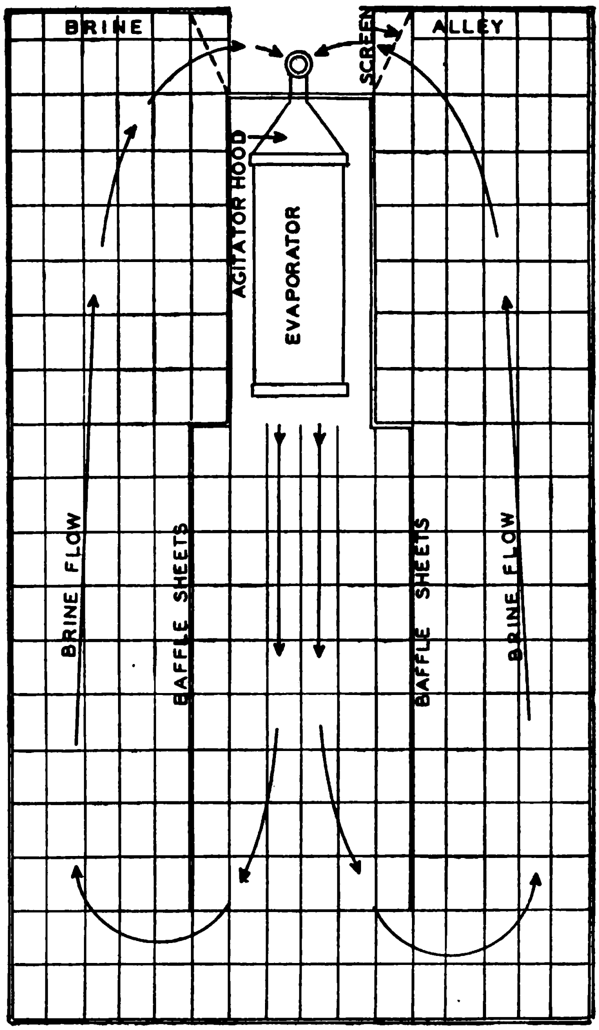

FIGURE 16.—One type of ice tank framework lay-out.

d. Double-swing inner doors are intended to prevent the wasting of refrigeration when the refrigerator doors are opened. Workmen should pass carefully through these doors in order to avoid collisions. Those wearing eyeglasses should be particularly careful to guard against being struck by swinging doors.

30. Sanitation.—*a.* Sound judgment and careful attention to sanitation are essential in handling all food products.

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b. The entire premises should be maintained in a neat and orderly manner. Merchandise should be handled carefully to avoid damage.

c. No smoking should be allowed within the cold storage rooms. "No smoking" signs should be placed in all the rooms and compartments of the plant.

31. The ice plant section.—The manufacture of ice is not usually a function of Army refrigeration units in the field, yet there are some ice-making plants set up and operating. The ice-making plant described herewith is one in which all principles of operation are presented, but no operating procedure is given. The ice plant consists of a freezer tank, an evaporator, and an agitator; it uses brine as a secondary refrigerant. These, together with thermometers, gages, piping, valves, can lifts, etc., are the essential parts of the ice-making plant.

a. Ice tanks are practically standard in design and arrangement but may vary in construction and in accordance with the need for which they are erected. In permanent installations, the tank is constructed of sheet steel. The metal sides are reinforced with angle-iron ribs to maintain rigidity, and are braced by the tie strips or girders running from one side to the other. These tie strips support the floor or checkerwork, so named from the pattern of the covers of the ice cans immersed in the brine for freezing. This top checkerwork may be of wood (fig. 16) or of steel rods and angle iron; it may separate a single can or a group of cans when a can-grid or basket-pulling method is used. This method pulls a nest of the frozen cakes at a time, and is used where ice is required in large quantities. For such a method, the tank must be designed in cell groups, and must be provided with an arrangement for a hoist.

b. Ground-floor tanks are usually laid on a 4- to 6-inch thickness of corkboard, which is placed on a concrete foundation. The cork is cemented with the joints in all directions so that there is no point where one joint falls immediately over another below it. Wall insulation is usually a 6-inch solid corkboard, or an 8- to 12-inch thickness of ground cork. A protective coating of asphaltum is sometimes applied to the inside surface of the steel. Ice cans usually rest on wood strips laid on the tank bottom, or are hung from the top framework or checkerwork. Insulation on top of this framework is usually effected by wood lids 2 inches thick that may cover individual cans or groups of cans.

c. Sizes of tanks are determined by calculation of the dimensions and numbers of cans required to give the needed daily ice production capacity, plus the space required for the evaporators, agitators, etc.

d. Some tanks are fitted with a drain outlet through the bottom, but

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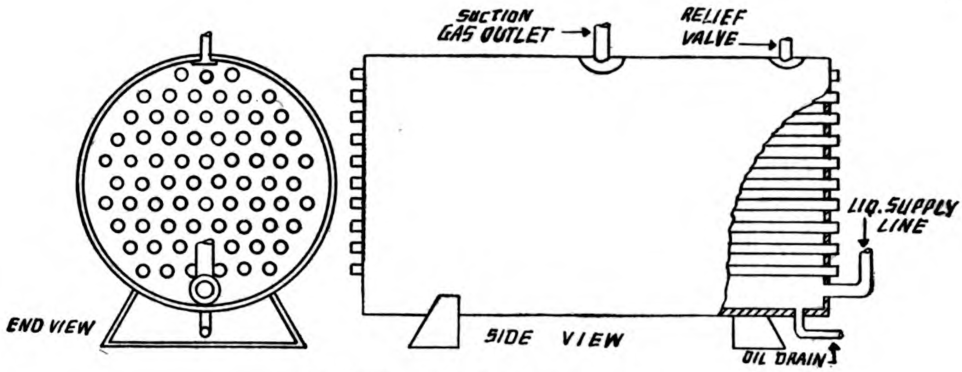
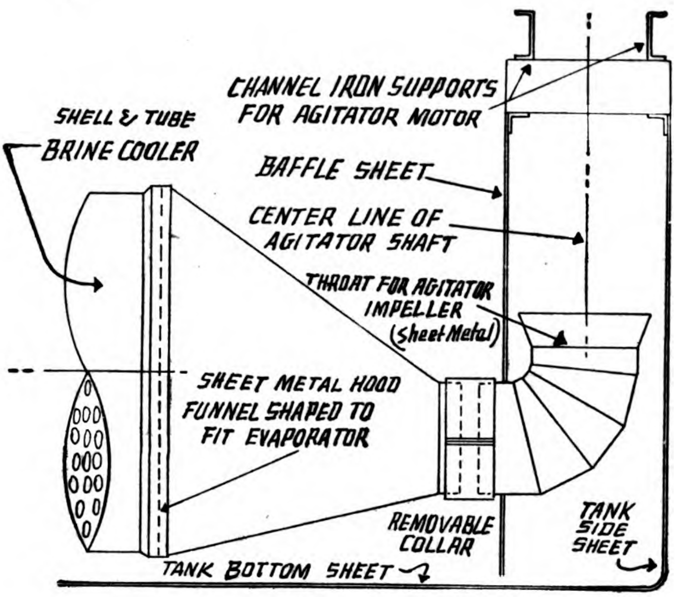
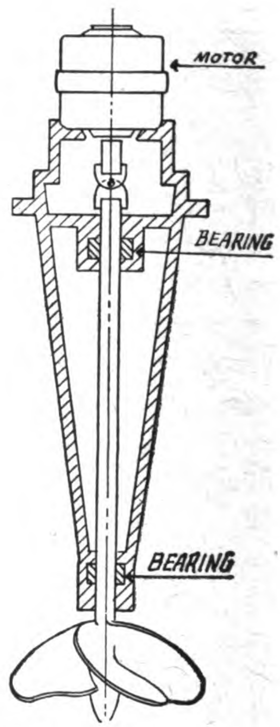


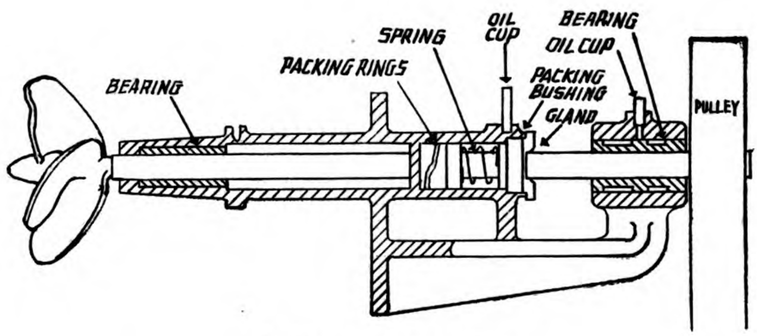
① Shell and tube evaporator.





② Hood for agitator and evaporator.

③ Vertical agitator.



④ Horizontal agitator.

FIGURE 17.—Agitators, evaporator and hood.

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all should be equipped with an overflow outlet to prevent the brine level from rising high enough to flow over into the ice cans.

32. Evaporators.—Evaporators for ice tanks are numerous in basic design and accessories, and vary widely in effectiveness and adaptability to different conditions. The function of all evaporators is to remove heat from secondary refrigerants such as air, water, and (as in ice making) brine. The cold brine is then circulated between the ice cans immersed in the brine. Here it picks up heat from the water in the cans and thus freezes the water into ice. There are three types of evaporators for use in connection with the operation of an ice-making plant: the shell and tube, the vertical coil, and the trunk coils. Each of these types may be found in numerous designs.

a. Horizontal shell-and-tube evaporators.—The horizontal shell-and-tube evaporator (see fig. 17 ① and ② is a heavy shell or tank into which the refrigerant liquid is released to expand and absorb heat. This refrigeration is exerted upon the walls of numerous tubes which have been sealed into the heads of the tank and through which the brine is circulated. These tubes are open on both ends, and are welded to the heads where they enter the tank and where they come out on the other side. They are merely ducts to carry the brine from one end of the tank to the other; in doing so they give up the heat to the refrigerant. Several advantages of this type of evaporator may readily be seen by a study of the illustration. One advantage is that a large amount of evaporator surface can be localized into a small area in the ice tank. A second advantage, which is an inherent characteristic of its design, is that proper hooding (fig. 17 ② produces adequate brine velocities through the tubes which results in efficient heat transfer rates. A third advantage is that the liberated refrigerant gas has a very short route through the evaporator to the suction outlet. Multiple installations of shell-and-tube evaporators, both in parallel and in series, are used on large tanks, while a single unit may be used on a small tank. The movement of the brine through the evaporator is speeded up by the use of agitators. The vertical agitator (fig. 17 ③ is used when the installation permits the use of this type in the throat, as shown in figure 17 ②. The horizontal agitator is used by driving through the side of the tank.

b. Vertical coil evaporators.—Vertical or simple coil units (fig. 18) are constructed by connecting adjacent horizontal pipes at alternate ends, either by welding, bending, or using a fitting known as a "return bend." (This pipe must not be galvanized if ammonia is the refrigerant used.) The coils are placed vertically; that is, one pipe above the other, usually with one coil between each row of ice cans, and one coil outside of each outer row of cans. The open end of the bottom pipe of each coil connects to one cross pipe known as a "liquid header."

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The open end of the top pipe of each coil connects to a cross pipe of considerably larger diameter, known as a "suction" or "gas" header. Liquid supply and oil drain lines are connected to the liquid header and the gas is removed through a suction line connected to the gas header. One advantage of this type of coil is that the brine has nearly continuous contact with both cooler coils and ice cans. A disadvantage is the length of pipe through which the liberated refrigerant must pass before reaching the suction outlet. Another disadvantage

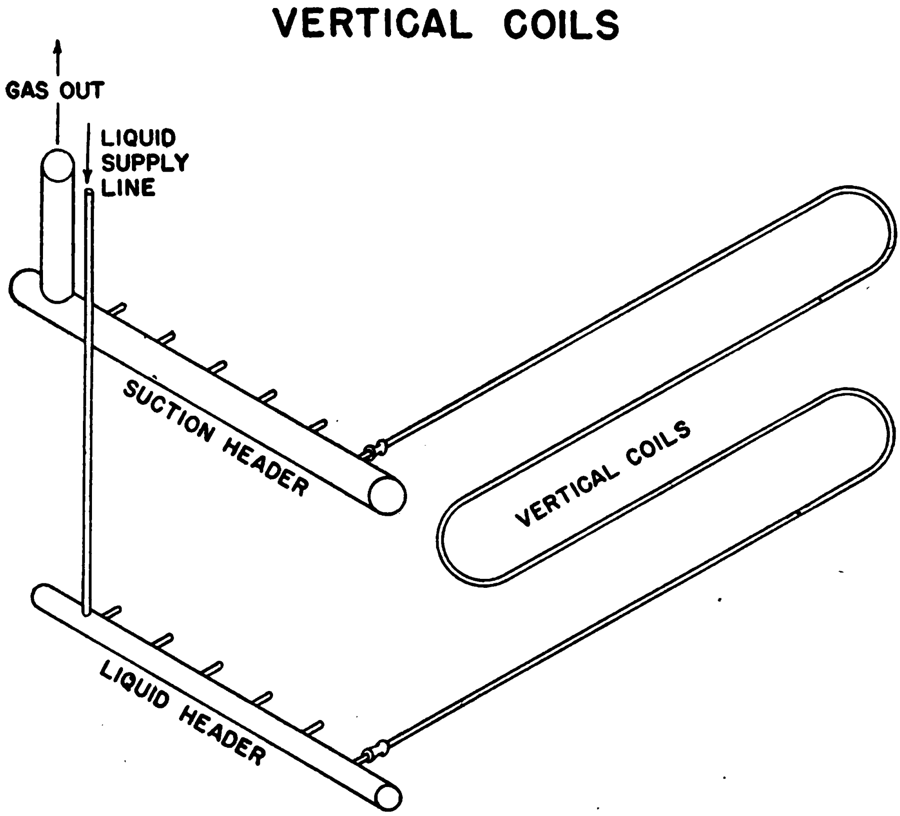

FIGURE 18.—Vertical ice tank coil.

is the difficulty of maintaining desired high velocities of refrigerating medium between the coils.

c. Trunk type coils.—These type coils are so numerous in patented styles and designs that no attempt will be made to show one. The best description of them would be a number of vertical or simple coils placed almost in contact with one another and interconnected between coils and pipes with headers running vertically, horizontally, diagonally, and radially. The object of this design is to increase the advantage of the shell-and-tube evaporator.

(1) The freezing tank is usually equipped with thermometers of either the recording or the indicating types. Readings from these thermometers are compared with temperatures of refrigerant gas

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leaving the evaporator. Such readings determine whether the correct brine temperatures and temperature differences are being maintained for efficient operation.

(2) The ice cans, made of galvanized sheet steel, are filled with water and placed in the brine tank as nearly submerged as possible without permitting the brine to flow into the clear water in the can. These cans are usually of such size as to mold a 300-, 350-, or 400-pound cake, although the portable ones used under field conditions will mold a cake of about 50-pound size. As the ice freezes from the outside of the can inward the unfrozen water is agitated by means of air introduced to the ice can. Unless the water has been filtered or is absolutely pure, the impurities will accumulate in the center or core. In order to avoid a dirty center, impurities are pumped out by a coresucker. Clear, fresh water is introduced by a core-filler, and the freezing is then completed.

(3) A hoist (power- or hand-driven) is used to lift the ice can or cans out of the brine tank. The hoist is mounted on a wheeled overhead track, which is in turn mounted on a wheeled bridge that spans the brine tank. The bridge runs on overhead rails and can therefore move the suspended ice cans to any position of the tank or adjacent areas. Cans are normally removed or pulled in groups of 2 to 24, depending on the number of cans in the brine tank. Hoists handling two or three cans in a group usually lift by electric power, but are pushed around the plant by hand.

(4) After the ice-filled can is hoisted from the brine tank and allowed to drip for a moment, it is lowered into a tank of water at approximately atmospheric temperature and allowed to thaw until the cake of ice is freed from the sides of the can. This thawing tank is usually constructed of sheet steel and has a fixed overflow outlet that maintains the required depth of thawing water at all times. Plants without a thawing tank have a water spray that strikes all sides of the ice can when it is up-ended on the ice-can dump. The heat from this water spray melts the ice until it loosens and slides down a chute to the ice storage room. The empty ice cans must be refilled and replaced in the brine tank. When empty ice cans are handled in groups of two or three, they may be replaced in the brine tank and filled there with a portable can-filler. This device is similar to the core-filler, except that it has an automatic float-controlled valve that stops the filling process when there is sufficient water in the ice can. Some installations include a water softener, which removes the impurities from the water used for ice-making. Generally, Army ice-making installations are constructed in the above manner. Both the large, fully equipped plants and the small portable units operate on exactly the same principles.

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Chapter 4

MOBILE REFRIGERATION

33. General.—Mobile refrigeration is refrigeration adapted to conveyances. It can be grouped under three main headings: refrigerator cars, refrigerator trucks, refrigerator boats and ships. The principles covering refrigerants, insulation, air circulation, humidity, etc., are identical with those for stationary cold storage, with the additional factor of vibration to be considered.

34. Refrigerator cars.—*a. Construction.*—(1) Refrigerator cars are iceboxes on wheels. Insulation consists of hair felt for the walls and roof, and cork for the floor, reinforced by building paper and matched lumber. Hair felting 2 inches thick is installed in continuous sheets from doorpost to doorpost, around the sides and ends of the car. Usually, two layers of felt are installed in the walls and three or four courses in the roof. Great care should be exercised to close the joints where the walls meet the roof and floor. Bunker hatch covers and doors are equipped with spring attachments that effectually seal the opening when hatchways and doors are closed. Floors must be waterproofed.

(2) Air circulation in refrigerator cars is produced by gravity. In all bunker and brine-tank type cars, a wooden bulkhead, or apron, is placed about 6 inches in front of the bunker or brine tanks in each end of the car. These serve a triple purpose: they prevent damage to the face of the bunkers or the tanks by loads shifting in transit; they protect the load in each end of the car from the extreme cold of the refrigerant; and they facilitate air circulation to and from the refrigerant. A space of 12 to 14 inches between the top of the bulkhead and the ceiling allows a flow of air from the top of the car to the bunkers; a similar space between the bottom of the bulkhead and the floor allows the cold air from the bunkers to flow out beneath the load. Bulkheads are either built in or hinged. Most of them are solidly built, the latest type being insulated with paper, hair felt, or cork. The insulating material is placed between two layers of wood construction and protects the load from freezing.

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b. Ventilation.—(1) In transporting certain fruits and vegetables, ventilation is as essential as refrigeration. These commodities are living things; they breathe and give off carbon dioxide. A carload of fresh fruit approaching ripeness, closed up tight in an uniced refrigerator car with a temperature above 50° F., will in 24 hours generate heat enough to injure it, and in 2 or 3 days will as thoroughly cook it as if it had been subjected to steam heat.

(2) Packers' refrigerator cars are not provided with any means for ventilation, since the commodities usually transported therein do not require ventilation. Provision cars of the bunker type, used to transport fruits and like commodities, are provided with means for ventilation. This is usually accomplished by raising the hatch covers over the bunkers and allowing some air to flow into the car through the forward hatchways and out at the rear hatchways.

c. Uses for refrigerator cars.—Refrigerator cars are not used for refrigerator transportation alone. In many instances they are used to protect commodities from severe outside temperatures. For example, good insulation is required to protect eggs in midwinter shipments. Potatoes and other vegetables are frequently shipped in refrigerator cars during severely cold weather. Sometimes, heating units are placed in the brine tanks to further protect the products against freezing. Most heaters are ineffective; they do not heat the car uniformly, and frequently produce poisonous gases. A new heater developed by a Canadian railroad consists of a charcoal heater installed underneath the car and stoked from the outside at stops. Antifreeze liquid is circulated through pipes underneath the floor racks of the car.

d. Influence of color on cars.—Since refrigerator cars are exposed to the sun's rays and are susceptible to heat absorption from that source, it is desirable that they be painted with colors that will refract light. Experiments have shown that the internal temperature of a car with a white roof may be as much as 8° lower than that of a car with a black roof. Most refrigerator cars are painted with colors that will not absorb the sun's rays.

35. Method of cooling refrigerator cars.—*a. Ice.*—The majority of refrigerator cars use ice as the refrigerant. In general, ice-refrigerated cars are of two types: bunker type and brine-tank type.

(1) In the bunker type car, the bunkers (or ice containers), extend across the car from side to side at each end. The bunkers are of two types: box type, and basket type.

(*a*) In the box type bunker, the ends and sides of the car form three sides of the bunker. The front is either of slatted wood or of wire or other metal construction. In any case, it must be sufficiently

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closely meshed to prevent the coarse ice from escaping, but also sufficiently open to allow free access of air.

(*b*) In the basket type bunker, all four sides are of heavy wire, strip metal, or slatted-wood construction. The sides and backs of the baskets are placed about 4 inches from the sides and ends of the car in order to allow a free circulation of air on all sides of the refrigerant. Some basket bunkers are divided vertically from front to back through the middle by a 4-inch passageway, to further facilitate air movements.

(*c*) The floor of the bunkers of both types is of wood or wire construction and allows for drainage of water produced by the melting ice. The ice capacity of the box type bunker is greater than that of the basket type; and the single basket has a greater capacity than the divided basket. Ice capacity varies with different makes of cars. Box type bunkers have a capacity of from 11,000 to 14,000 pounds of ice per car; single baskets about 10,400 pounds, and divided baskets about 7,400 pounds of ice per car.

(*d*) Bunker type cars are used almost exclusively in the fresh fruit and vegetable trade where low temperatures are not required. They are not adapted for transporting meat. The bunkers are filled through hatches above the bunkers. The cakes of ice are broken up only sufficiently to facilitate handling. No salt is used. A drip pan beneath the bunker catches the water from the melting ice and discharges it through a trap in the floor of the pan. Some bunker type cars are equipped with collapsible bunkers to increase the loading space when loaded with lading not requiring refrigeration.

(2) The brine-tank type car is designed for the use of salt with ice. It produces temperatures lower than is possible with the bunker type car using ice alone. The use of brine tanks is necessary to retain the brine, not only to get the benefit of its low refrigeration, but also to prevent dripping. Brine, if allowed to drip from the car, damages metal car parts, as well as rails, tie plates, bridge members, etc., of the right-of-way. All roads have established icing stations where refrigerator cars are iced at about 24-hour intervals. Here the excess brine is drawn from the tanks and replaced with additional ice and salt.

(*a*) Eight brine tanks are used in each car—four side by side across each end. Each tank has a capacity of about 700 pounds of ice and salt, or 5,600 pounds per car. The tanks are filled through hatches at the top, and the brine is drawn off through a trap gate at the botton. In addition, a drip pan is placed beneath the tanks to catch any condensed moisture that might drip from the surface of the tanks. The tanks are made of heavy galvanized sheet iron. Refrigeration is produced by the air of the car coming in contact with the cold surfaces of the tanks.

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(*b*) The ice used in brine-tank cars is crushed much finer than for the bunker type cars. It is necessary for the salt to be intimately mixed with the ice. Best results are obtained when the ice is in small lumps ranging from the size of an egg to that of a man's fist. If ice is crushed fine, it mats together and prevents uniform settling. Pack-ice brickettes used for icing cars are made in oval shape to prevent too tight packing. Too large lumps of ice prevent close contact with salt. During the icing process, the ice is tamped down in the tanks to prevent large air pockets which would retard refrigeration.

(*c*) The salt used is coarse rock salt known as "commercial number 2", the pieces running from 1/8- to 1/4-inch in diameter. The quantity of salt used depends upon the kind of product being transported, the season of the year, the section of the country being traversed, etc. For shipment of fresh chilled meats, from 5 to 10 percent of salt is ordinarily used. In the heat of summer, somewhat larger quantities are used. For shipping frozen meats, fish, and other products which must be maintained in a frozen condition, larger percentages of salt are necessary. For carload shipments of frozen meats, from 15 to 20 percent of salt is adequate to maintain a frozen condition, unless the outside temperature is very high. Lower car temperatures can be obtained by the use of additional salt up to 25 percent. The use of greater than 25 percent of salt is not productive of lower temperatures. Brine tanks should be drained at least each 24 hours en route or until the car is unloaded, and the same percentage of salt used at each re-icing as was used at the original icing.

(*d*) A modification of this type of ice tank has been introduced recently. It is designed to carry low-temperature brine reinforced by ice and salt. It is asserted that the initial icing of such cars will maintain an even temperature for 4 days without re-icing. Precooling is done by spraying brine against the inner surface of the brine tanks. The brine enters through the hatchway at the top and is drawn off at the bottom and returned to the house system. Precooling is accomplished in much less time than with ice and salt. After precooling, 4,500 pounds of ice and salt are used and the tanks filled with brine. The cost of refrigeration by this system is said to be much less than when ice and salt are used.

(*e*) Another type of tank has been developed. The bunkers lie beneath the roof along the entire length of the car, and are loaded through numerous hatchways in the roof. This arrangement has the advantage of applying cold at the highest point and of giving more space (approximately 20 percent) for pay load. Its greatest drawback is the possibility of dripping, which is guarded against by placing trays beneath the tanks to catch the drip and direct the flow of air.

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b. Solid carbon dioxide for car refrigeration.—(1) In the shipment of frozen fish particularly, temperatures of zero or below are desirable. Such temperatures are difficult to obtain by the use of ice and salt. Experiments have been made with the use of solid carbon dioxide for refrigerating cars for such shipments. Specially designed cars, or equipment altered for the use of this refrigerant, are in use, with the following reported advantages:

(*a*) Lower and more constant temperatures.

(*b*) One icing is sufficient for a period of 7 to 10 days of travel, resulting in a saving in time and the necessity for re-icing.

(*c*) The action of gas resulting from sublimation of the solid CO_2, when allowed to discharge into the car, is said to be beneficial to the product by controlling mold and bacterial growth, etc.

(2) Experiments are being conducted with the use of solid CO_2 as a booster for water-ice refrigeration. The solid CO_2 is placed in baskets or bags and suspended from the ceiling over the load. This results in somewhat reduced temperature and, with some products, in benefits from the action of the CO_2 gas. Such application of the refrigerant is not altogether satisfactory since full benefit of the refrigerant is not obtained. However, auxiliary equipment for the correct application of the refrigerant is now being installed in some refrigerator cars with excellent results reported in both reduction of temperature and economy. It costs from $16 to $20 to precool, ice, and re-ice a refrigerator car in transit, varying with the distance traveled, weather conditions, cost of ice and labor, etc.

c. Mechanical refrigerator cars.—This kind of car is a product of recent development and has arisen from the desire for lower shipping temperatures than are furnished by ice cars. As yet, their use is limited, (largely to the frozen fish trade), but is being adapted to other industries. Both the compressor and absorption systems are used.

(1) Compressor systems are variously arranged. Some have a power take-off from the axle of the car, with an auxiliary motor to drive the compressor while the care is not in motion. Others are operated by gasoline engines, and one late type is operated by a Diesel engine. The engines are installed either in compartments built beneath the cars, or in compartments in one end of the car outside the insulated body. Some engines are water-jacketed. The fuel tanks are usually carried beneath the car and are of sufficient size to provide fuel for a complete trip. The refrigerating medium may be ammonia, methyl chloride, sulphur dioxide, or other medium. The evaporator may be a series of pipes attached to the ceiling or installed within bunkers in the ends of the car. In some cases, brine tanks are installed in the bunkers to hold the temperature when the car is not in

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motion. The condenser may be installed in the engine compartment or in a compartment superimposed upon the roof. They are usually air-cooled, and some of them are fan-driven.

(2) *Absorption system.*—Silica gel is used almost exclusively in the absorption-type refrigerator car. The equipment consists of three parts: the evaporator, the condenser, and the absorber which contains the silica gel.

(*a*) The evaporator consists of parallel pipes running through the length of the car beneath the ceiling and connected to a lateral header. Here the liquid refrigerant (sulphur dioxide) is expanded to a gas. Troughs are suspended beneath the pipes to catch dripping and prevent wetting the load beneath.

(*b*) The condenser is air-cooled and consists of pipes underneath a protective covering on the roof of the car.

(*c*) The absorber consists of two parts and is located in the end of the car outside the insulation. It requires little space. The fuel supply is carried in tanks suspended beneath the car, and is sent to the burner under reduced pressure through a pressure regulator. Vertical pipes welded to a header contain the silica gel and are encased within fireproof insulated housings. The gas burners are placed beneath the pipes; they furnish the heat for activating the gel. The fuel used is propane gas. About 135 pounds of gas is required per ton of refrigeration. Temperature is controlled by means of two thermostats placed in the car at points most liable to temperature fluctuation. The thermostats control the supply of gas fed to the burners.

(*d*) Silica gel is pure silicon dioxide. It is very porous and capable of absorbing large quantities of gases or liquids which can be driven off again by activating the gel with heat. This process can be continued indefinitely with no physical change in the gel. About 1,000 pounds of the gel is used in the absorbing tubes. The equipment is divided into two absorbing and heating units. These work alternately; while one is on the absorbing phase, the other is discharging.

(*e*) *Advantages.*—The advantages claimed for this type of car are:

1. Lower and more constant temperatures can be maintained throughout the car.

2. Longer cars can be used since the refrigerant is distributed to all parts of the car.

3. More loading space is available since the equipment requires much less room than the ice bunkers.

4. The gas containers hold enough fuel for nine days, and therefore obviate the necessity for stopping to refuel.

36. Refrigerator trucks.—*a. Development.*—With the experiences of the development of the refrigerator car as a background, the

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development of refrigerator trucks has been rapid. The greatest stimulus toward their development was the building of hard roads. Trucks are particularly useful in serving points not convenient to railroads. In many instances, they can deliver more promptly than railroads.

b. Design.—Truck design is based upon such factors as length of route, number of stops, size and kind of load, weather and climatic conditions, road and traffic conditions, etc. Upon these factors are based the size of truck body, the number of compartments, size of doors, kind and thickness of insulation, kind of refrigerant, etc.

c. Types.—There are seven general types of refrigerator truck bodies:

(1) *Insulated body without refrigeration.*—This type is effective for transporting chilled products for short distances only. It represents the lightest construction of refrigerator truck bodies and provides for the maximum of load space. It needs only about 2 inches of high efficiency insulation. It is used in the bakery, candy, and similar trades.

(2) *Insulated body with refrigeration for hot months.*—These usually have collapsible racks or bunkers for the refrigerant, and can be dismounted during cold weather. Construction is similar to that mentioned above, with a minimum of insulation thickness.

(3) *Refrigerated with water ice.*—This type is used where low temperatures are not desired. The refrigerating cost is low, but the labor cost of handling is high. It has the disadvantages of requiring considerable space for the refrigerant and the additional weight of the ice, which reduces the pay load. Also, provision must be made for either disposing of or holding the water resulting from the melting ice.

(4) *Refrigerated with water ice and salt.*—Lower temperatures are obtained than with ice alone. This type has all of the disadvantages of the water-ice truck with the additional necessity for disposal of the brine and corrosion of metal parts by the salt.

(5) *Refrigerated with solid carbon dioxide.*—This type has the advantage of requiring less space and less bulk for the refrigerant, thus allowing a greater pay load; there is no liquid to dispose of; a lower degree of temperature can be obtained; and there is no deterioration due to moisture. In addition, the CO_2 gas, if discharged into the truck body, has a preservative action upon the product as it retards mold growth; and if discharged into the insulated space, it aids insulation. Its chief disadvantage is its higher cost, compared with the cost of ice. If not properly regulated, it may produce temperatures that are too low.

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(6) *Refrigerated with eutectic (frozen brine) system.*—Sodium chloride brine is used. It may be frozen in tight containers (cartridges) or in a flake-ice machine and thereafter compressed into blocks. The brine freezes so rapidly the salt does not crystallize out. It is heavier and more bulky than solid CO_2, but less so than ice and salt. It is capable of holding rather uniform temperatures from 15 to 18 hours. The cartridges are removed at the end of the run and replaced by frozen ones.

(7) *Refrigerated with mechanical units.*—The compressor type is most commonly used. The power take-off is made from the truck axle or from the main truck engine drive shaft while the truck is in motion, and by the use of a motor while at rest; still others have self-contained refrigerator units. The weight of the equipment has been a disadvantage, but equipment of much lighter weight is now being developed.

d. Application of refrigeration to truck bodies.—The methods used are varied. The simplest form is a rack in one end of the truck upon which block ice is placed. Because of their weight and bulk, and difficulties of caring for the drip, the use of ice and ice with salt has been in large measure discontinued. The majority of modern truck bodies are designed for refrigeration by solid CO_2, eutectic fluid, or mechanical units. In the most recent development for CO_2 trucks, the bunker is placed outside the truck body and fed through outside hatchways, with metal fins projected into the truck body to aid in the rapid transfer of heat. The solid CO_2 rests upon the plate to which the fins are attached, and keeps them cold as long as any of the refrigerant remains. This has been found to be very efficient form of heat transfer. When this equipment has a well-insulated body, temperatures well below zero can be easily maintained. Brine installations are heavy and bulky, and for that reason are little used in truck refrigeration except in the form of eutectic fluid. Eutectic brine is frozen at low temperatures ($-30°$ F.) in cartridges which are installed either in racks in the truck body or on finned plates in bunkers. In some installations, the brine is in stationary tanks and is frozen during the time the truck is in the garage. In mechanical refrigerator truck units, the refrigerant is, for the most part, expanded in coils or plates hung beneath the ceiling of the truck body. To save space, some installations are in compartments beneath the truck body; but these require two fans, one to circulate the air within the body, and the other to drive the air through ducts to the refrigerating units. With the exception of some fan installations, circulation of air within refrigerator truck bodies is by gravity, as is the case in practically all refrigerator cars. Temperature can be controlled in all mechanical installations by the use of thermostats which regulate the flow of the refrigerant.

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CO_2 refrigeration can also be controlled by regulating the rate of sublimation.

e. Truck insulation.—(1) Truck insulation material must yield the maximum of insulating effect, be reasonable in first cost, and in cost of installation, light in weight, moistureproof, flexible, and long-lived. As in car insulation, many materials are used for this purpose. Hair felt and other hair preparations are commonly used in the walls and roof, and pressed cork in the floor. In addition, there are several patented products that seem to be giving exceptionally good results. The use of aluminum foil is increasing. This is the lightest of all insulating material, weighing about ¼-ounce per board-foot measure. It is of low conductivity, due to the refraction of radiant heat and low convection air spaces. It is applied in successive layers of crumpled aluminum foil.

(2) Eighty percent of the heat leakage in trucks comes in through the walls, but only 20 percent through the opened doors. The following is given as a general guide to insulation requirements:

Temperature desired	*Insulation thickness (inches)*
45° F.	2 to 2½
35° F.	2½ to 3½
10° F.	4 to 5½
0° F.	5 to 6½

Doubling the thickness of insulation halves the amount of heat that will pass through it. The effectiveness of insulation is increased if the inner wall is completely isolated from the outer; that is, there should be as few structional connections (such as bolts) as possible.

37. Refrigerator ships.—*a.* Refrigerator ships differ from stationary refrigerator plants only so far as their construction and operation require. The same principles of insulation, humidity, air circulation, and refrigerants apply. With the exception of some fishing boats equipped for freezing fish at sea, refrigerator vessels are not designed for freezing fresh products but to transport chilled products or products already frozen. Freezers, therefore, are of the holding type, which carry a temperature of approximately 20° F. For the most part, ammonia and CO_2 gas are the refrigerants used, using compression machines and ocean water for condensing.

b. Ocean refrigerated shipments now include not only chilled and frozen meats, but butter, cheese, and other dairy products, tropical and subtropical fruits, and other perishable commodities. For this trade, ships are provided with special equipment for the accurate control of temperature, humidity, and air circulation.

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CHAPTER 5

REFRIGERATION METHODS IN THE ARMY

SECTION I

GENERAL

38. General.—Army Regulations provide for refrigeration at permanent Army posts. Army refrigerators are built to supply specific needs, and vary in size from a unit of several large walk-in storage rooms of 5,000 cubic feet capacity or more for post use, to the medium-sized refrigerators for officers' and enlisted men's messes. At many stations, plants are set up to manufacture ice and store it for issue. This equipment is built in accordance with Army specifications as to size, construction, insulation, etc. For the most part, because of low initial cost and comparative cheapness of ice, iceboxes are installed, though many of the newer units are provided with facilities for conversion to mechanical boxes by the installation of mechanical units. At posts where new quarters are being erected, most installations are of the mechanical type.

39. Field expedients for iceboxes.—*a.* When troops are away from post, it frequently becomes necessary to make substitutions for company iceboxes. Troops operating within a localized area with available railroad facilities may possibly secure a refrigerator car. If ice is available, a refrigerator car will supply the refrigerator needs of a division for the storing and issue of perishable supplies. In summer weather, such a car will require from 1 to 2 tons of ice a day for re-icing after the initial icing which requires 7 to 11 tons. A packer's refrigerator car is more desirable for this purpose than a railroad refrigerator car, since the former has overhead racks from which fresh meats can be hung. Such a car is in frequent use, so some provision must be made to prevent too great loss of refrigeration.

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through the open doors. If the car is kept well filled with provisions, a vestibule can be constructed outside by draping paulins over a frame, or canvas curtains may be attached to the inside of the door frame to close the opening and prevent too rapid transfer of heat while not materially interfering with the passage of men or supplies through the doorway. If more room is available within the car, a vestibule can be made by stretching canvas curtains from side to side across the car on each side of the doorways. (See fig. 19.)

b. Where refrigerator cars or regulation boxes are not available, other expedients may be utilized. A double-walled box, the wall packed with sawdust, shavings, straw, or even with sand, makes a fairly good refrigerator if ice is available. Its efficiency is further increased by sinking it into the ground about 2 feet and by protecting it from the direct rays of the sun by a canopy of canvas, branches of trees, hay, etc. (See fig. 20 ①.)

c. If ice is not available, an iceless refrigerator can be built at little expense. It uses water for cooling purposes. A wooden frame with solid wood ends is covered on three sides with nonrusting wire screening. A door of the same construction is made to fit tightly on the fourth side. Canton flannel is then applied tightly on all sides, with provisions for fastening the flannel when the door is closed. At the top, the flannel extends far enough to reach into a pan of water placed on top of the cabinet. Water must be kept in the pan at all times. The flannel strips act as wicking to carry the water over the edge of the pan and down the sides of the cabinet. Since cooling depends upon evaporation of moisture, the box should be set where there is a good circulation of air. Obviously, it should be set in the shade. With proper facilities, a temperature as low as 55° F. can be obtained from such a cabinet. The box should not be more than 24 inches square and not more than 5 feet high. As many shelves as are desirable can be placed in the cabinet. The flannel coverings should be washed once a week for sanitary reasons. This can be expedited if the coverings are attached by means of buttons, and if an extra cover is available for use while the first is being laundered. (See fig. 20 ③.)

d. Natural flow of water can frequently be utilized for refrigerating or air-conditioning purposes. Water may at times be diverted from a mountain stream and made to flow over the roof and sides of a building, or over a tarpaulin-covered field icebox, thus lowering the temperature appreciably. Such an arrangement will also add to the effectiveness of an iceless refrigerator placed in the room. (See fig. 20 ②.)

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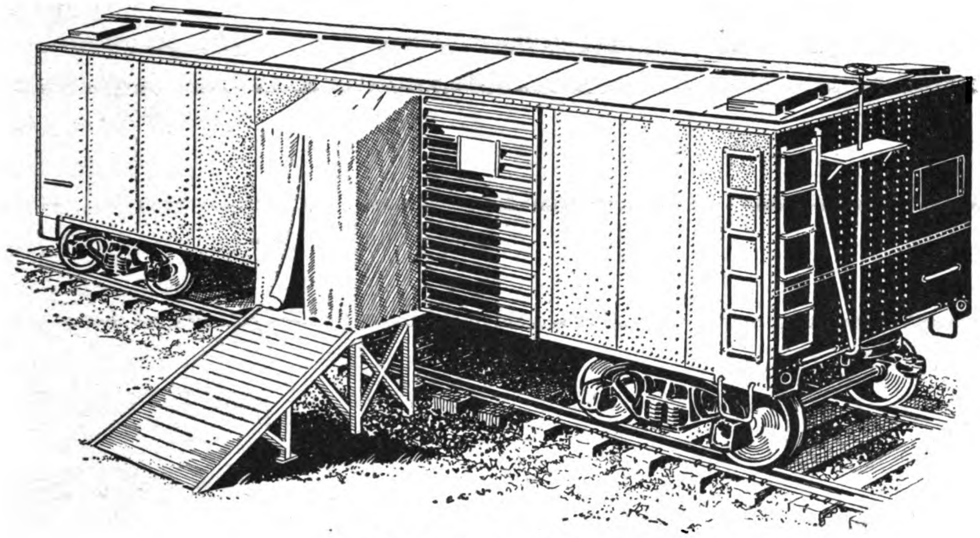
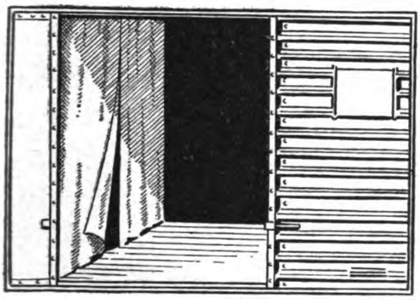
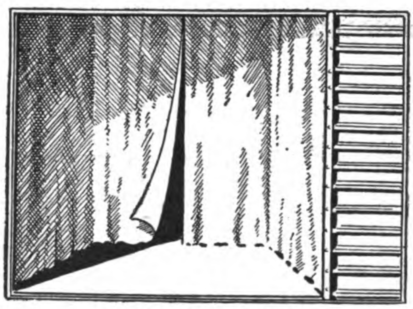


① Vestibule outside.



② Ends partitioned off.

③ Tarpaulins over door openings.



④ Vestibule inside.

FIGURE 19.—Methods used to prevent refrigeration loss.

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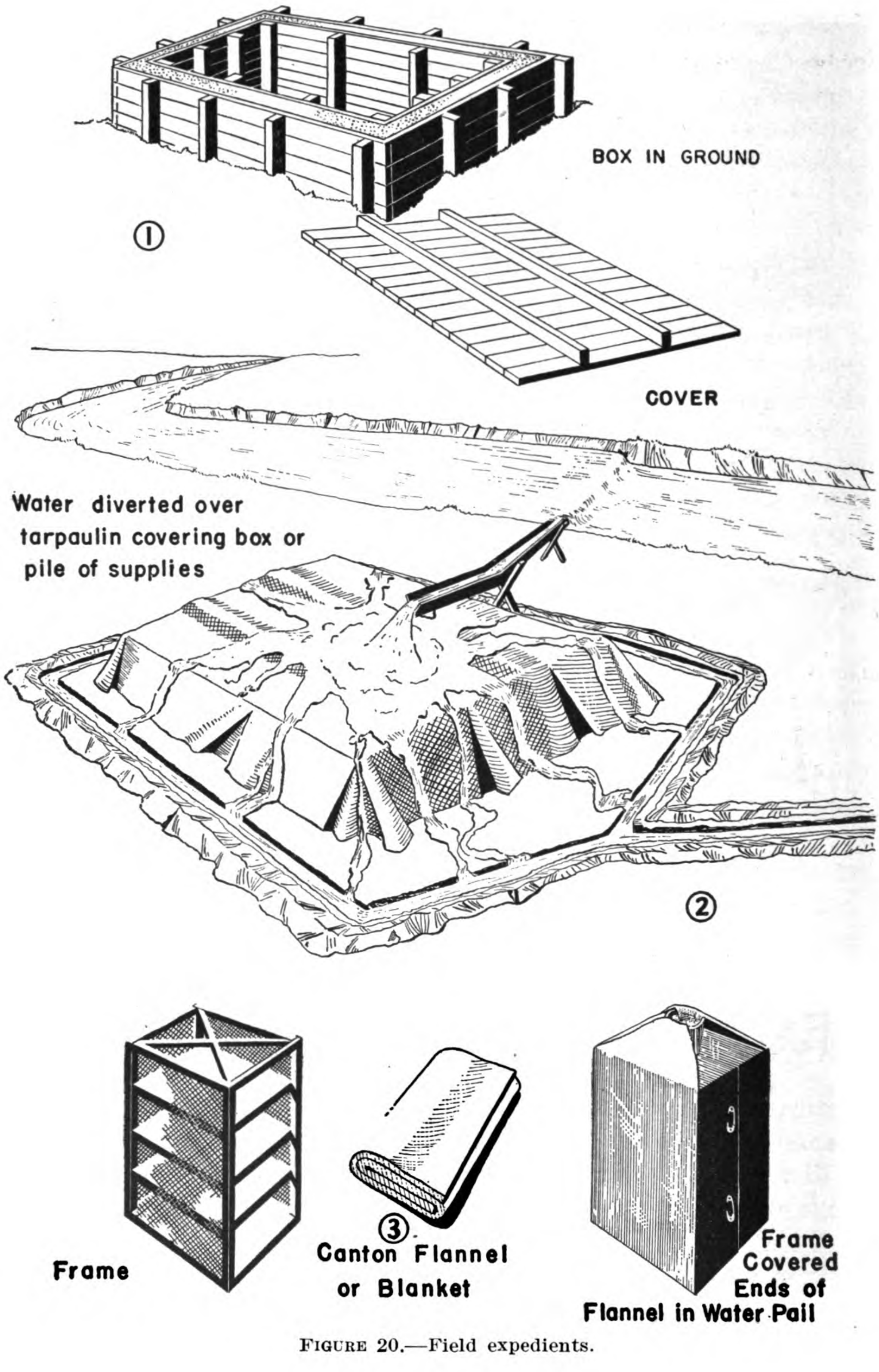

FIGURE 20.—Field expedients.

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40. Mobile refrigeration trailers.—*a.* The mobile refrigerating company is equipped with insulated van body trailers of which there are several designs. The latest is of end-opening construction with the gas-engine-driven refrigeration unit installed in a bulkheaded compartment in the forward end of the trailer. (See fig. 21.) Other designs consist of electric-driven machines operated from the driving assemblies on the truck-tractor. But the self-contained unit is the most satisfactory because it permits the maintenance of refrigeration when the vehicle is immobile and separated from the tractor. These trailers are drawn by 4- to 6-ton truck-tractors.

b. There are several types of evaporators, such as flat-plate units hung on the wall, and on the ceiling of the body, and the radiator type evaporator assembled with the engine compressor. These machines are assembled on a single frame with an intake grill on one side of the body to cool the engine radiator, and exhaust grills on the opposite side through which the heat from the condensing unit is driven out. There are several manufacturers of this type of equipment, and a careful study of the maintenance manual shipped with the refrigeration equipment is necessary for the proper operation and care of these trailers. (See figs. 21, 22, 23.)

c. The great weight of the equipment and the insulated body make operation difficult or even impossible over some types of terrain. The refrigeration unit in the fore part of the trailer and the heavy all-wheel drive units and assemblies at the rear of the truck-tractor concentrate a considerable weight at that point and the tractor-trailer therefore bogs down readily on soft terrain. The improvement of flotation may possibly overcome this failure, but the present type vehicles are most satisfactory when used over roads, even of the most primitive sort, or over terrain that is fairly flat and solid.

41. Portable refrigeration units.—The preservation of foods must be continuous, and at points where there are no cold storage facilities, these refrigeration facilities must be created. The Army has developed portable prefabricated storage units, measuring approximately 9′0″ by 12′10″ by 7′6″ high, and containing complete refrigerating units. (See fig. 24.) They are shipped knocked down and set up wherever they are needed. These units are complete in themselves, but often several are banked or grouped together in order to increase storage capacity or to provide varying degree of cold storage by adjusting temperatures of each section. Small-scale ice-making plants have been developed for situations which require the use of ice. These plants create 50-pound cakes of ice, but the operation of the equipment requires great care, and except where ice is required, the use of the cold storage unit is preferable.

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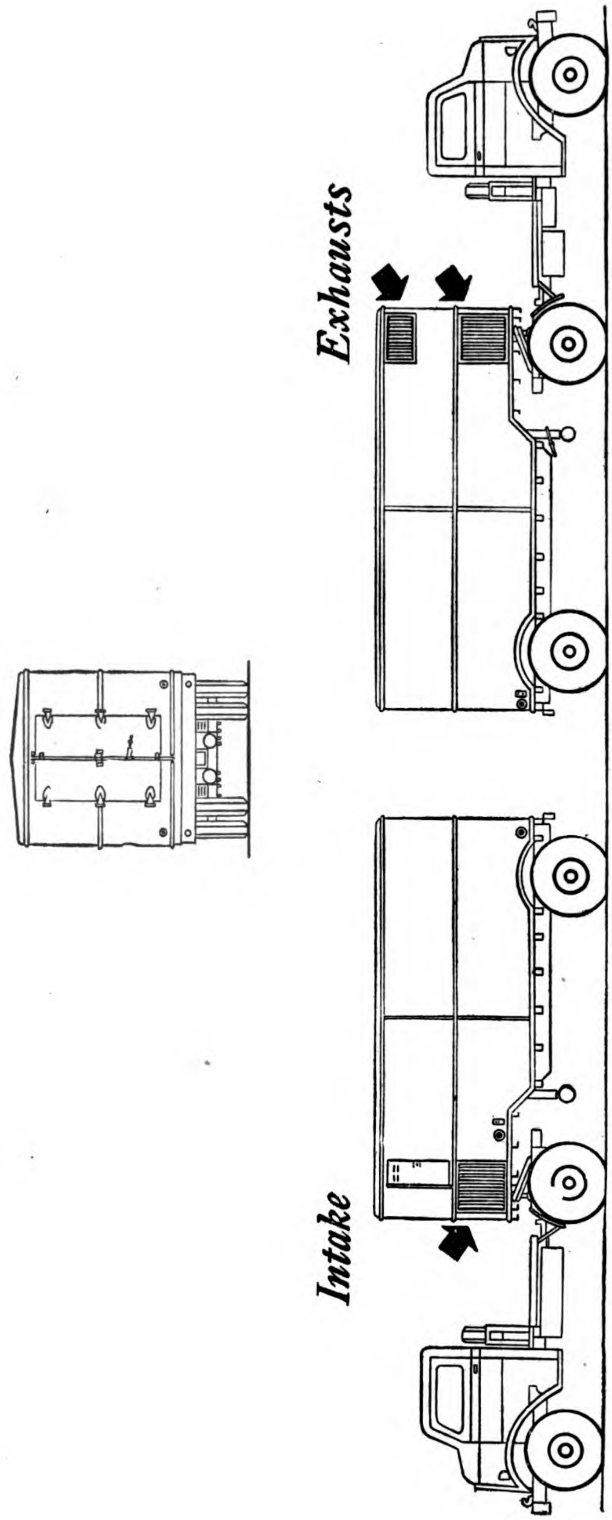

FIGURE 21.—Army mobile refrigerator truck.

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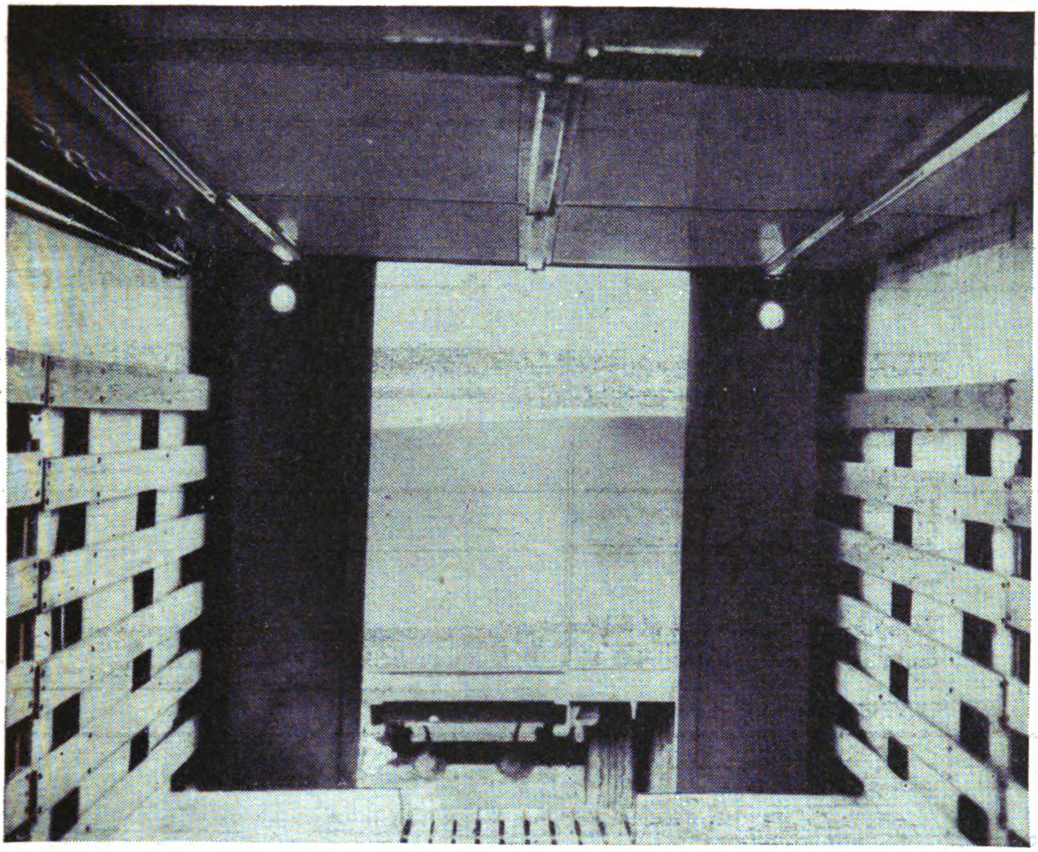

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②

FIGURE 22.

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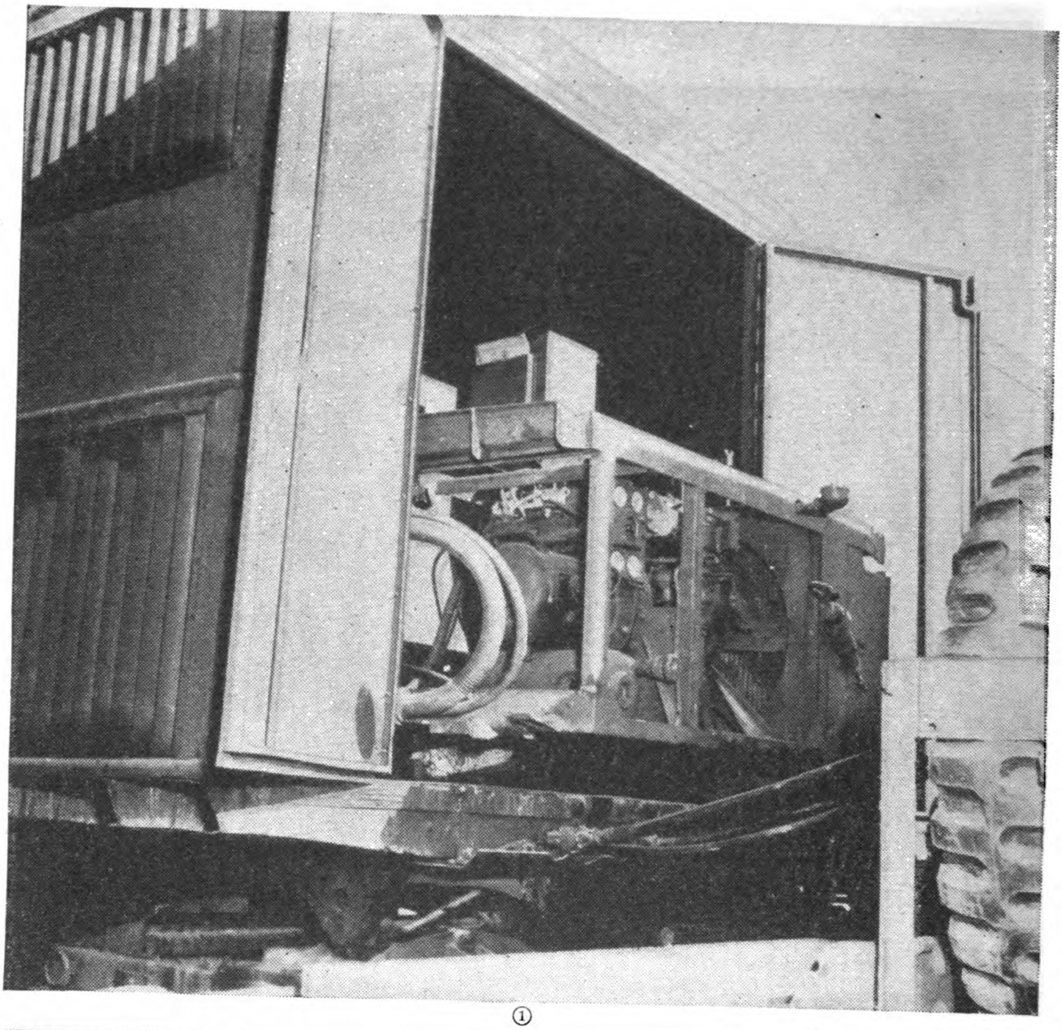

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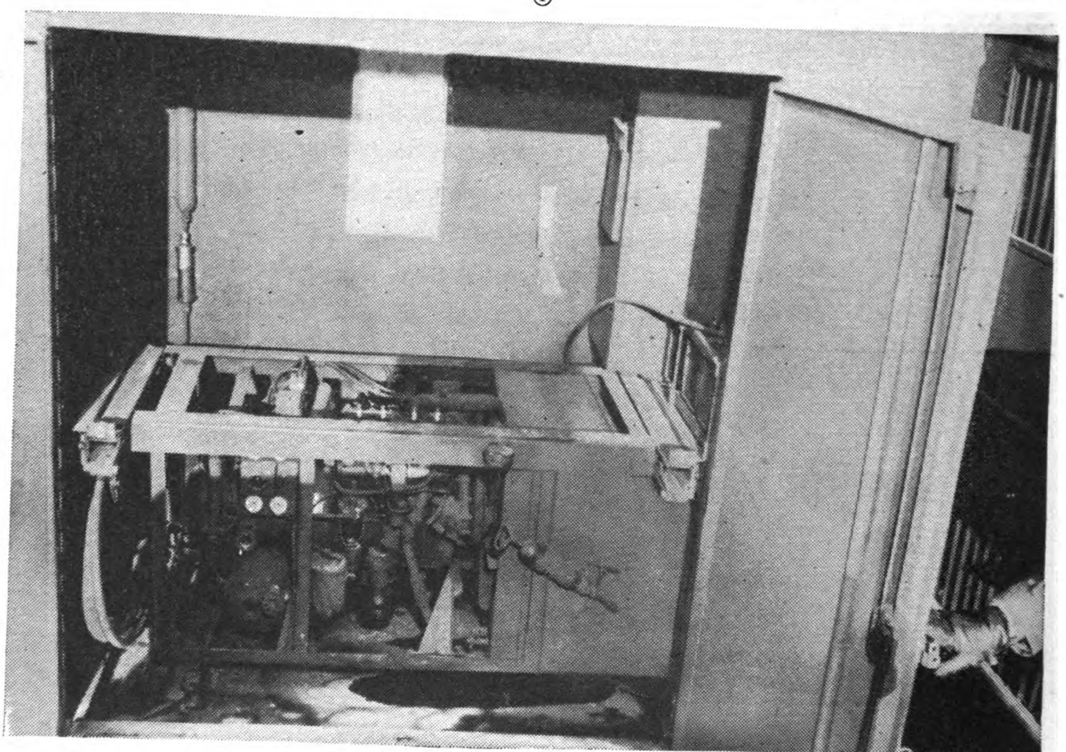

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FIGURE 23.

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42. Fixed refrigeration units.—The fixed refrigeration units of the Army are of various sizes, depending upon the size of the combat area they are supplying, or upon the posts, camps, or stations they serve. The functions of this type of plant are described in section III.

Section II

MOBILE REFRIGERATION COMPANY

43. Function.—The mobile refrigeration company is an organization set up to provide refrigeration facilities where frozen or fresh foods and perishables are being transported to combat elements.

a. Rail refrigerator-cars are the prime means of moving these perishables from cold-storage warehouses. Perishables are placed in the same train with other class I rations and forwarded to the division railhead.

b. In many areas, railroads either do not exist or have been rendered useless by enemy action. In such areas Army cargo trucks transport rations forward to the using units. Truck convoys will form and function under the control of the regulating officer. Refrigeration trailers carrying perishables will be incorporated into these convoys.

c. Where rail transport with refrigerator cars is available but using elements are a considerable distance from the railhead, a system of transportation must be established between the railhead and a prearranged point midway to the front where the trucks from combat elements will be met. Here perishables will be transferred from refrigerator trailers which have been sent forward from the railhead, finally being turned over to the using units.

44. Organization.—The company is made up of a company headquarters and three platoons of refrigerator trailer units. Platoons are broken down into three sections of three van trailers each which are accompanied by the necessary truck tractors.

a. Headquarters includes the following personnel:

(1) First sergeant, who performs the administrative duties normally his responsibility under the company commander.

(2) Technical sergeant (refrigeration engineer), who will supervise the care and operation of the refrigeration equipment of the unit as a whole, issuing instructions for the proper operation of the sections' equipment and setting up the rules for their maintenance and inspection.

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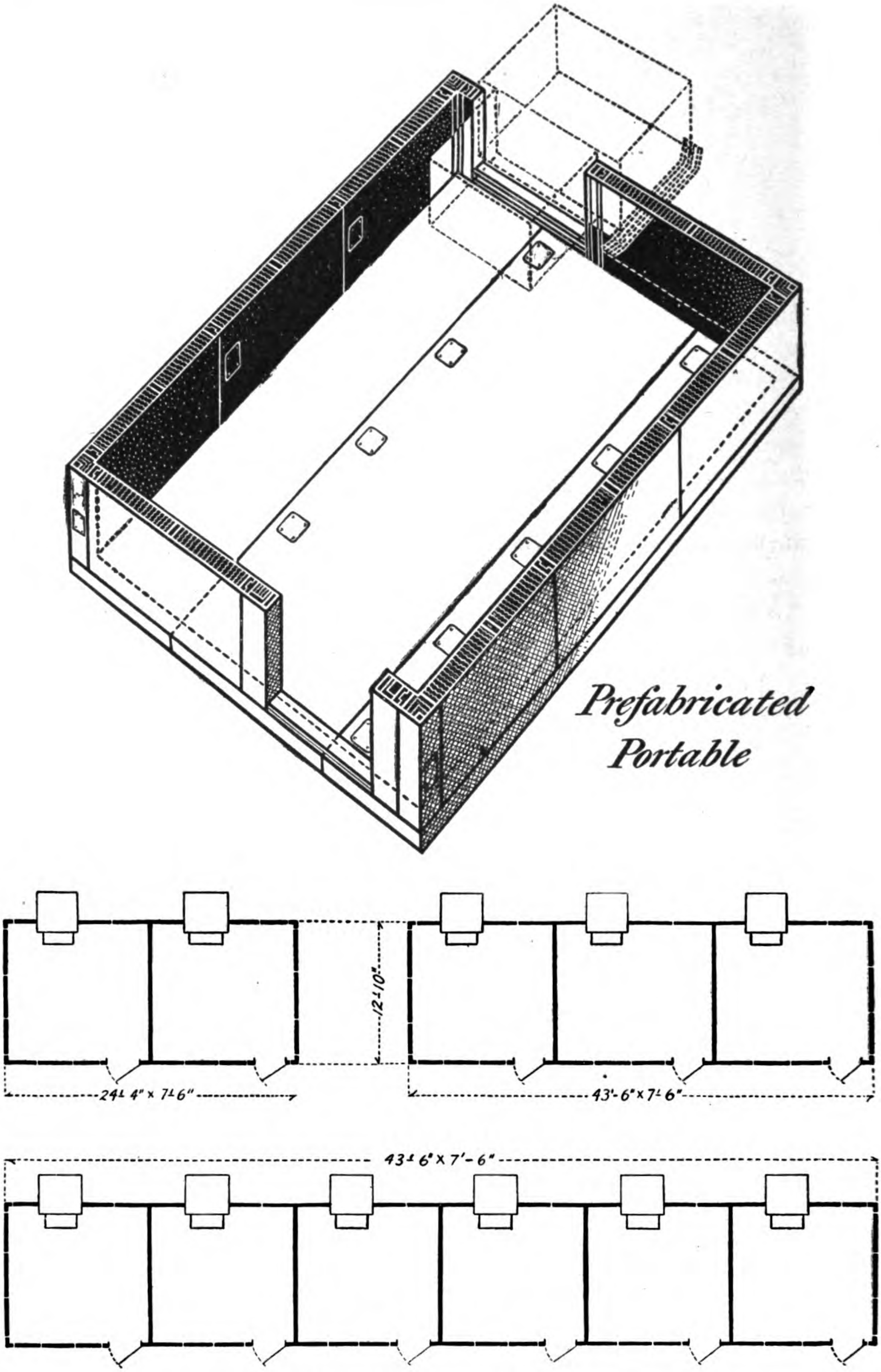

FIGURE 24.—Portable storage warehouse.

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(3) Mess sergeant, who performs his normal duties of feeding the troops.

(4) Supply sergeant, whose duty is the supply of the troops.

(5) Motor sergeant, who is responsible for supervising the operation and care of the vehicles of the company as a whole.

(6) Cooks, who may also be assigned to the platoons when operating separately.

(7) Motor and refrigeration mechanics, who set up small repair installations for the company as a whole.

b. Each platoon has a headquarters comprised of a commissioned officer, a platoon sergeant and a chauffeur, and three operating sections. Each operating section drives three of the refrigerator van trailers. The refrigeration mechanics assigned to these sections ride with the chauffeurs, act as their assistants, and make emergency repairs on the refrigeration mechanism.

c. Operation of refrigeration equipment.—The van trailer is a highly efficient unit, comprised of an insulated body and provided with several different types of cooling systems. Constant inspection and adjustment are necessary to keep them performing efficiently. To assure this care, the men charged with the operation and maintenance of both the heavy automotive and the refrigeration units must be well trained, and must make a thorough study of the maintenance manuals provided with their equipment.

SECTION III

QUARTERMASTER REFRIGERATION COMPANY

45. General.—*a.* The quartermaster refrigeration company is an organization set up to operate the storage warehouses and ice plants for the Army, and in some instances, to perform the necessary abattoir operations when food animals are procured in the theater of operations. The ice-plants, set up at strategic locations, are usually large-scale fixed installations in buildings erected for the purpose, or found available for such installation. A recent development is the operation by small detachments, of prefabricated, portable storage and ice-making plants, erected as required at strategic points.

b. The company is organized with a veterinary detachment and four platoons. These are the headquarters, butchery, refrigeration, and

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cold storage platoons. The butchery platoon is activated only when and if abattoir activities are required.

46. Company headquarters and headquarters platoon.—*a. Company headquarters personnel.*—(1) The captain in command (a refrigeration engineer) is responsible for the proper operation and maintenance of the refrigeration equipment, administration, sanitation, training, discipline and supply of the company. Final responsibility for the discharge of the duties of the company and the welfare of the personnel rests with the commander, although he may delegate most of the actual work to subordinates.

(2) The first sergeant, under supervision of the company commander, is responsible for the preparation of all reports, rosters, and routine correspondence pertaining to the organization; he has general supervision of supply and messing of personnel of the organization; he is responsible for the presence of personnel at formations and roll calls as directed by the organization commander.

(3) The mess sergeant (staff sergeant) performs the function of feeding the company. The company commander has intrusted him with the job of securing and preparing rations in a manner which will give satisfaction to the men. At the same time, he will organize the work of the cooks and cooks' helpers so that there will be no waste, and so that the kitchen and storerooms will be kept in such a way as to assure sanitary conditions, pleasant atmosphere during the mess, and wholesome appetizing meals. Morale of the organization depends upon the mess sergeant meeting and fulfilling his responsibilities.

(4) The supply sergeant (staff sergeant) is charged with equipping and sheltering the men; he provides the tools and supplies necessary to keep the plant in excellent operating condition; he secures and issues to the men the arms and ammunition needed to defend themselves; he is responsible to the company commander for the safeguarding of equipment; he submits requisitions to augment or replace that property, and maintains all records necessary for issues of the property to individuals.

(5) The company clerk (corporal) works under the first sergeant, and is responsible for the preparation of correspondence and the performance of such other clerical duties as may be assigned to him. When no unit personnel section is available, he will assist the first sergeant in the performance of unit personnel duties.

(6) There are two more men assigned to this headquarters; both are privates, one an orderly to the company commander, and the other for general service.

b. Administrative section.—(1) The master sergeant (superintendent) is the assistant to the company commander, and supervises the

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technical administration of the duties prescribed for the various sections and platoons of the company. His work differs from that of the first sergeant (whose prime duty is the welfare of personnel) in that he is responsibe for the proper performance of the technical operations assigned to the company.

(2) The operation of the administrative section is the responsibility of a technical sergeant (chief clerk) under the supervision of the company commander. The chief clerk is responsible for the proper distribution of incoming orders, tallies, requisitions, and correspondence, and for maintaining files and insuring that prompt and proper action is taken on correspondence; he has general supervision of the office, the stock record cards, and office personnel. His office force consists of headquarters clerks and stock record clerks.

(3) The watchmen assigned to the section are responsible for the proper protection of the refrigeration plant and supplies. There are also men assigned for general duties.

c. Plant service section.—This section, in charge of a staff sergeant (maintenance foreman) is charged with the maintenance of plant, building, grounds, machinery, and equipment. The personnel of this section includes a carpenter, an electrician, a plumber, a welder, and a storekeeper. There are ¾-ton weapons carriers assigned to this section as service wagons, and three soldiers assigned as chauffeurs.

47. Butchery platoon.—*a. Function.*—This platoon, commanded by a lieutenant, is activated only when abattoir activities are required. It is responsible for—

(1) Cutting quarters of meats (beef, veal, pork, etc.) into wholesale market cuts.

(2) Cutting wholesale market cuts into cuts suitable for mess use.

(3) Boning beef and other meats.

(4) Slaughtering and dressing meat animals.

(5) Operating a defrosting room.

b. Duties of personnel.—(1) The second lieutenant supervises all operations of the butchery platoon; he coordinates its operations with those of the cold storage platoon and headquarters platoon.

(2) The staff sergeant (foreman) and his assistant, a sergeant, have direct charge of all work details, and supervise all killing, cutting, and boning activities.

(3) Butchers (9) and butchers' helpers (9), who perform all meat cutting and boning, should be experienced knifemen.

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(4) Checkers and weighers will maintain records of the weights of finished product and wastage and of receipts and issues.

(5) Meat handlers (18) handle all the meats between trucks and cutting and boning tables, and transfer the cut meats to packages or to trucks for shipment or distribution.

(6) Basic personnel perform duties not otherwise specifically assigned.

c. Meat-cutting equipment.—Cutting and boning rooms should be arranged so that the introduction, cutting, boning, packaging, and removal of the meat can proceed with the least amount of labor. Saws, cutting and boning tables, packaging tables, etc., should be placed so as to allow a progressive movement of the meat. Each platoon should be provided with facilities for sharpening knives and saws (grindstones, whetstones, files, etc.). The sharpening of band saws requires expert technique and special equipment. Knives should be rough sharpened on a grindstone and finished on a smooth whetstone. During periods of use, the edge should be kept smooth and straight by the use of a smooth, polished steel. Power saws should be inspected frequently, should have adequate guards to prevent injury to workmen, and should be kept in perfect repair. Boning and cutting tables should be made of nonodorous wood sufficiently thick and heavy to be substantial and firm. Exposed metal parts of tables upon which knives could strike will cause injury to the cutting edges and lower efficiency. Tables and trucks with which meat comes in contact, and saws, knives, hooks, and other tools used to handle meats must be kept scrupulously clean. All sawdust resulting from the sawing of meats must be removed. Table tops and other equipment must be washed or otherwise cleaned daily. Wet floors favor the growth of bacteria and mold. Fresh, clean wood sawdust helps to keep floors dry and the air sweet. Meat should never be allowed to come in contact with rough walls. The temperature of cutting and boning rooms should be kept under 60° F. Butchers, boners, and meat handlers should dress in outer clothing that can be readily washed and sterilized.

d. Cutting and boning.—The cutting and boning of carcasses and wholesale market cuts of beef, veal, mutton, lamb and pork, the scaling and dressing of fish, and the drawing and cutting of poultry are described and illustrated in TM 10–405.

(1) *Frozen meats.*—Frozen carcass beef can be cut into pieces small enough to be used in the kitchen only by means of a power-driven band saw. While hand saw may be used, the process is too slow and difficult for quantity production. With a band saw, one man can saw a frozen beef carcass into wholesale market cuts in approximately 6 minutes, and into kitchen size cuts (roasts, etc.) in 10 to 20 minutes,

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depending upon the number of small cuts. At that rate, three band saws operating 24 hours a day would be needed to cut enough beef to feed 120,000 men daily. Frozen quarters cannot be boned until after they have been defrosted. Proper methods of defrosting meats and fish are described in TM 10–405. Defrosted meat should be kept cold until it is to be used. It is far better to deliver frozen beef to the kitchens in a frozen state. Frozen meats, if wrapped and packaged, can be safely shipped and held without refrigeration for 24 hours. All meats, whether chilled or frozen, should be protected from contamination by insects, dirt, etc., by adequate wrapping or packaging. The butchery platoon should be provided with facilities for wrapping and packaging cut meats for distribution.

(2) *Chilled meats.*—If beef and other meats are to be boned, boning should be accomplished before freezing. Otherwise, frozen beef must be almost completely defrosted before it can be boned. Boneless beef, properly packed, requires only about one-third the storage space required for frozen quarters. The boning of fresh beef is described in conjunction with beef cutting in TM 10–405. An experienced butcher can cut a 600-pound fresh chilled carcass of beef into wholesale market cuts in approximately 12 minutes, and can bone one carcass in 1 hour. At that rate, 275 man-hours of labor, or three shifts of 12 men working 8 hours each would be required to bone beef for 120,000 men. Additional men are required to place quarters on the cutting table and remove the cut meat, bones, etc. Chilled meats must be kept under refrigeration continuously until they are to be prepared in the kitchen. In the present war, most cutting and boning is being done by commercial organizations.

e. Check weighing.—All carcasses and wholesale market cuts should be checked and weighed when entering the cutting room, and cuts should be checked and weighed out. There is always a loss resulting from cutting or boning meats, varying from one-half of 1 percent to 1½ percent. Loss in weight in bones, fat, and sinew resulting from boning cascass beef of specification grade averages about 25 to 27 percent.

f. Slaughter of live animals.—When called upon, the butchery platoon may be required to slaughter and dress beef animals for troops on the march or at points not accessible to prepared supplies. In order to comply with Army regulations, veterinary service should be provided during the slaughter of food animals, the handling of dressed carcasses, and the disposition of edible byproducts and inedible offal are described in Subsistence Bulletin No. 18, Fresh Meats.

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(1) *Slaughtering equipment.*—For small-scale slaughter, the following very simple equipment may suffice:

(*a*) *Methods of tying animals for stunning.*—Animals may be put in a knocking pen, or may be snubbed to a tree, post, or a ring in the floor by means of a rope.

(*b*) *Hammer for stunning.*—A 3½-pound, double-headed sledge with beveled edges and a 36-inch handle is best for stunning animals, but any similar sledge can be used.

(*c*) *Knives for sticking, skinning, etc.*—While knives such as those used in cutting beef may be used, knives designed specially for sticking and skinning are preferable.

(*d*) Receptacles for blood, unless facilities are available to drain the blood away.

(*e*) Receptacles for viscera.

(*f*) *Saws and cleavers for splitting carcasses.*—Hand saws are used in temporary installations, and power saws for rump sawing in permanent installations.

(*g*) Hoists to raise carcasses for bleeding, eviscerating, and hide dropping.

(*h*) Shackles and gambrels for suspending carcasses.

(*i*) Brushes for washing dressed carcasses.

(*j*) Hot water for washing carcasses, and steam for cleaning and sterilizing the equipment.

(*k*) Chill rooms for chilling carcasses and edible organs (livers, hearts, tongues, etc.).

(*l*) Racks upon which to handle edible organs for chilling.

(*m*) Facilities for disposal of fats (chilling tanks, hashers, rendering tanks, etc.).

(*n*) Facilities for disposal of inedible products (stomach contents, feet, horns, etc.).

(*o*) Facilities for sharpening edged tools.

(*p*) Facilities for washing outer clothing.

(2) *Requirements.*—For very limited slaughter, butchering may be done in the open with crude and temporary equipment. For large-scale slaughter, however, permanent installations with modern facilities are essential. To supply beef for 120,000 men, approximately 275 beef cattle averaging 1,000 pounds live weight must be killed daily. The dressed carcasses from these cattle should weigh about 165,000 pounds. This beef must be chilled. Nineteen thousand pounds of hides would require salting and 8,500 pounds of edible organs require chilling and handling. Thirty-six thousand pounds of inedible waste would have to be disposed of by burning, burying, reduction to fertilizer, or other means. Approximately 50 expert butchers using

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modern equipment and working 8 hours would be needed to kill, dress, and handle the byproducts from 275 beef cattle. A much larger number of inexperienced men would be required for the same task.

48. Refrigeration platoon.—*a. Function.*—The principles of refrigeration, the operation of a refrigerator plant and the manufacture of ice are described in other sections. Personnel of the refrigeration platoon should familiarize themselves with these principles. The functions of the refrigeration platoon are to operate all refrigeration machinery (including ice-making equipment), to have charge of all refrigerants (including the making of refrigeration brine), to be responsible for the maintenance of proper temperatures within the refrigerated areas, and to operate humidifying equipment, ozone machines, and other installations incident to the maintenance of proper refrigeration conditions. In an installation such as is contemplated, two refrigerants, Freon–12 (dichlorodifluomethane, CCl_2F_2) and ammonia (NH_3) are most commonly used. Sharp freezers are refrigerated by direct expansion of ammonia or by low-temperature calcium chloride brine, holding freezers by calcium chloride brine or direct expansion of ammonia, and chill rooms by sodium chloride brine. The compression system of expansion and recovery of gas is the most commonly used. Compression machinery may be driven by electricity or steam. Steam boilers may be heated with oil, coal, or other satisfactory fuels that may be available. Water-treating equipment may be necessary for ice manufacture if the available water is very hard. Maintenance of equipment is the function of the plant-service section of the headquarters platoon.

b. Duties of personnel.—(1) A lieutenant has general supervision of all activities of the platoon, and coordinates its work with that of the cold storage and headquarters platoons.

(2) The technical sergeant (engineer, refrigeration, and foreman) and his assistant, the sergeant (assistant engineer and foreman), are charged with supervision of the refrigeration and air-conditioning machinery, ice-making, brine-making, etc.

(3) The refrigeration mechanics and their assistants are charged with the actual operation of all refrigeration machinery.

(4) Oilers and temperature men record and regulate temperatures in refrigerated areas and attend to the lubrication of moving machinery.

(5) The duties of the firemen vary with the kind of equipment (automatic stokers) and fuel (oil, coal, gas) used.

(6) When refrigeration machinery is driven by electricity or internal combustion engine, operators to replace the firemen will have to be provided for the driving equipment.

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(7) Ice-pullers (laborers) fill, handle and empty ice cans and store the ice.

(8) Basic personnel constitute a labor squad for the performance of duties not otherwise assigned.

49. Cold storage platoon.—*a. Function.*—The cold storage platoon is charged with the safe and prompt handling of all perishable supplies at refrigerators. Sanitation inspections are conducted by attached veterinary personnel. They will place the various grades of perishables in the type of cold storage best suited for their preservation. (See ch. 3.) They will store the foods in holding-freezer compartments where the temperature is maintained at approximately 10° F. to keep frozen foods from melting, in chill-rooms at approximately 32° F., which holds fresh meats under proper refrigeration, and in ventilated storage rooms where commodities that would be destroyed by freezing are held to retard deterioration. This platoon also handles the sharp-freezing of meats, when such activities are carried on.

b. Duties of personnel.—(1) The officer commanding the platoon has general supervision of all cold-storage procedure and the handling of supplies, and coordinates the work of his platoon with that of the butchery, refrigeration, and headquarters platoons, and the attached veterinary personnel.

(2) The foreman (technical sergeant) and his assistant (staff sergeant) have charge of all work details. It is their duty to see that all supplies are handled promptly, safely, and in a sanitary manner.

(3) The checkers and scalers are to check, weigh, count, or otherwise verify quantities of supplies entering and leaving the cold storage plant.

(4) The freezermen receive loaded trucks, and spread, pile, or stack incoming commodities for freezing or storage, and load outgoing supplies on trucks or other conveyors.

(5) The platform men load all incoming and outgoing supplies on trucks or other conveyors.

(6) The truckers truck all incoming supplies from unloading docks to refrigerators and all outgoing supplies from refrigerators to defrosting room, cutting room, or loading dock.

c. Attached veterinary.—Under regulations, the Veterinary Corps is charged with the inspection of food supplies of animal origin and the sanitary handling of such supplies. It is the duty of attached veterinary personnel to inspect all meats and dairy products entering and leaving the refrigeration plant for compliance with specification requirements and for sanitary condition, and to inspect and pass upon the fitness for food of all animals slaughtered by the Army for food

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purposes. Sanitary inspection includes the determination of any spoilage or deterioration arising subsequent to the time of original inspection, sanitation of equipment, exposure of perishables to adverse conditions of temperature, humidity, foreign gas, etc. They may also be called upon to render technical assistance when necessary.

d. Inspection of incoming supplies.—A veterinary inspector should always be present at the cold-storage plant to pass upon the condition of perishable supplies. Cars and trucks used in transporting perishable supplies should be clean, sweet, and sound enough to protect the contents against adverse conditions. The temperature inside refrigerator cars and trucks upon arrival is usually a good criterion of the condition of the cargo carried therein, particularly if the period of travel has been long. The inspector should note these conditions in order to determine suitability of the contents for storage. An offensive odor emanating from a conveyance when it is opened should cause suspicion of the condition of the contents. Cars and trucks carrying meats and similar perishable supplies should have an inside temperature not higher than 40° F. If a higher temperature exists, the product should be carefully inspected for sliminess. Conveyances carrying frozen meats and other frozen foods should have an inside temperature not higher than 25° F. If inside temperatures are above 32° F., products should be inspected for defrosting. Products in which deterioration is evident should not be stored but should be used as soon as possible.

e. Check weighing.—(1) All products arriving for storage should be checked for net weight, count, or measure, depending upon the unit of purchase or storage. All products admitted to storage should have the net weight, number of units, or other data conspicuously marked on the outside of containers or wrappings. It is seldom necessary to weigh or check every parcel, but a check of a sufficient percentage should be made to determine that the marked weights or counts are accurate.

(2) Suitable handling equipment and scales are necessary for efficient service, and are furnished by Tables of Allowances. If equipment must be procured locally, the sizes which will do the work properly should be carefully selected; equipment that is too large takes up valuable storage space, and equipment that is too small wastes time and energy. Scales should be accurate and capable of check-weighing merchandise received and for weighing small issue orders.

f. Lot identification.—(1) An effort should be made to issue goods in the same order as received, except when a lot must be moved out quickly to avoid spoilage losses, and when another lot

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of the same commodity is in better condition for continued storage. Unless goods are moved out in rotation, except as above, some packages may remain at the bottom or rear of a pile so long that spoilage occurs.

(2) When large quantities of items are being handled, the lot-numbering system should be used. In this system, each individual day's shipment of any one product of like brand and grade and in like containers is assigned a lot number. Every package within a lot should be marked or stamped with the number of that lot in figures at least ½ inch high. Receiving, inventorying, and delivery records should carry corresponding numbers.

g. Handling of supplies.—The amount of labor required for unloading and storing supplies varies with the kind and adequacy of facilities present. For products in fiberboard or wood containers, ladder conveyors are desirable for short distances on the level or downgrade. For chilled carcass beef and wholesale market cuts, overhead rails and trolley conveyors offer the most rapid and easy method of conveying meats from unloading dock to storage room. The most frequently used conveyance for handling supplies is the truck, of which there are many kinds. The extent to which trucks should be loaded depends on the power available, the inclines to be traversed, the smoothness of the floor, the size of doorways, etc. Where tractors are available, trucks may be loaded heavier than where manpower alone is used. Packages should be piled securely on trucks to prevent falling, which might cause injury to attendants or to the product.

h. Use of storage space.—Cold storage plants represent a considerable investment, and are expensive to operate. Care should be taken to utilize all available space with economy. When a shipment of perishable items arrives at the warehouse, the superintendent should estimate the floor area required for each lot, and should then select a location and direct the building of the stacks.

i. Piling.—Items should be piled compactly. Starting at least 4 inches from the wall, stacks should extend in a single block to the edge of the center aisle. In rooms with ceilings 9 to 10 feet above the floor, stacks should be built up to a height of only 7 feet, so that cold air can circulate freely.

(1) *Dunnage.*—Floor dunnage should be used for sanitary reasons and to permit free movement of the cooled air under the stack. A suitable form of floor dunnage is 2 by 4 lumber in 4- to 6-foot lengths. Floor dunnage should be put out of the way after the stack has been removed.

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(2) *Ventilation within the stack.*—(*a*) Fresh fruits to be stored for a day or two need ventilation to cool them satisfactorily and to carry away any volatile products they give off.

(*b*) Cases for shell eggs are so constructed that sufficient ventilation is provided for short storage periods. However, for storage longer than 2 weeks, they should be properly separated by the use of thin pieces of boards.

(*c*) Boxes or cartons containing meat and meat products should be well separated by strips in order to provide suitable circulation of the cold air around each container.

(*d*) Meat and meat products which are solidly frozen and are at a temperature of approximately 10° F. when received may be stored without provision for stack ventilation. However, it is important that the stack be separated from the wall by a distance of at least 4 inches, and supported on the floor by dunnage at least 2 inches thick.

(*e*) Wooden laths may be used as stripping when it is necessary to provide ventilation between the tiers of a stack. The laths help to stabilize a stack composed of irregularly-shaped packages, and permit stacking to an economical height.

(*f*) In extreme cases (for example, in the stacking of packages of frozen boned beef), heavier pieces of lumber may be required for stripping between the tiers. A vertical bulkhead partition constructed of scrap lumber and placed at 10-foot intervals in a stack may also be helpful.

(*g*) Under no conditions, should any package of food or the food itself be permitted to come into direct contact with concrete pillars, walls, or floors.

j. Conservation of refrigeration.—During unloading, car, truck, and refrigerator doors should be kept shut as much as possible in order to conserve refrigeration. When the refrigerator is being filled or emptied, a doorman should be stationed at the door to prevent undue loss of refrigeration. Refrigerated receiving rooms aid in maintaining products in good condition during unloading. Whenever possible, entrances to refrigerators should be provided with airlocks (particularly in hot weather) in order to prevent the entrance of outside air directly into refrigerators. Airlocks are particularly needed at entrances to freezers.

k. Loading for distribution.—The loading of storage supplies for distribution to troops is approximately the reverse of unloading and storage procedure. Meats, either fresh or frozen, may have to pass through the cutting room for cutting or boning by the butchery platoon. When frozen meat must be defrosted for cutting or boning, such meat is delivered from storage to the defrosting room. In han-

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dling supplies from cold-storage rooms to cars or trucks for distribution, cleanliness of clothing and equipment is essential. Care must be taken to handle all supplies expeditiously in order to prevent loss of refrigeration and to prevent exposure of chilled or frozen products to the deteriorating influence of heat. Refrigerator cars should be properly precooled and iced before loading begins. Car temperatures should not be higher than those indicated for incoming cars. All racks, hooks, and other equipment with which products come in contact should be scrupulously clean, and conveyances should be free from foreign odors. Nonrefrigerated trucks carrying perishable supplies should be covered with paulins and other protective material. The temperature of such trucks can be improved by frequently showering the coverings with water.

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Appendix I

GLOSSARY

Absolute humidity.—Actual weight of moisture vapor in air expressed in grains.

Acid.—A substance typically soluble in water and sour in taste. It will redden vegetable blues, as litmus. An acid will neutralize alkalis by combing with them to form an acid salt.

Air agitation (clear raw water systems).—The process of admitting air into water and keeping it in motion while freezing within an ice can for the purpose of stirring and concentrating the impurities into the core. The impure core water is replaced with fresh water before the final freezing to insure a block of clear, sanitary, transparent ice.

Air headers.—The main supply pipes installed on the ice tank (at ends, sides or center) for conveying the air to the air laterals.

Air laterals.—The pipes used in clear raw water ice making systems, for conveying the air for agitating the water in the ice cans. They are usually installed on the freezing tanks or on the can baskets for delivering the air to the drop tubes or stationary tubes of each ice can.

Air orifice.—The control point through which the correct volume of air is permitted to pass to the ice cans at the working pressure on which operated.

Alkali.—A substance typically soluble in water and having a caustic taste. It is capable of changing a vegetable red to blue, as litmus, and will neutralize an acid.

Ampere.—The unit used in the measurement of electric current volume or rate of flow.

Brackets.—The fitting fastened to ice cans or laterals for suspending drop tubes in or near the center of each can for making clear raw water ice.

Braze.—A process of welding using bronze or brass. This process is not always actually fusion welding but is often similar to soldering in that the bronze or brass is often applied to a parent metal which has a higher melting point, such as cast iron.

Brine agitation.—The movement of brine in the freezing tank by the aid of an agitator or propeller, to facilitate the transfer of refrigeration to the water in the ice cans.

Brine cooler.—A round cylindrical receiver for receiving refrigerant; it has hollow steel tubes for passing brine to absorb the refrigeration

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from the refrigerant by a heat process, thereby cooling the brine passed by the brine agitator.

British thermal unit (Btu).—The quantity of heat required to raise the temperature of 1 pound of water 1° F.

Bulkheads.—Metal partitions usually in the center of the freezing tank to divert brine in certain directions for uniformly distributing refrigeration to the ice cans. They are also located at the brine cooler and between the brine cooler and the freezing tank proper.

Can basket.—Devices used to group cans for multiple handling.

Can guides.—Devices for keeping the ice cans straight in the freezing tank during the brine agitation and freezing process.

Can retainers.—Devices made in several designs to hold ice cans rigidly in position during the freezing process.

Carbon tetrachloride (CCl_4).—A noninflammable, highly volatile liquid. Weight approximately 16 pounds per gallon. Used in pump and pressure type fire extinguishers. It will not conduct electricity. It is often used as a cleaning fluid.

Charging valve.—A valve normally found on all systems, usually located in the liquid line between the receiver and expansion valve, used specifically for the purpose of adding or removing refrigerant.

Coefficient.—A number indicating the degree of a quality possessed by a substance. Differential coefficient is the ratio of the infinitesimal increase of a function to that variable on which the function depends.

Cold.—A term used to express the absence of heat or a condition of low heat intensity.

Compressor.—A piece of machinery used in a compression refrigeration system to extract the cool low-pressure gas from the evaporator and raise the gas pressure and discharge the high-pressure gas into the condenser.

Condenser.—A piece of machinery that receives high-pressure gas from the compressor and extracts heat from the gas reducing its temperature to its saturation point and then removing its latent heat of vaporization.

Condensing unit.—A term used to apply to an assembly of a compressor with driver, condenser, and receiver.

Conductance.—The quantity of heat transmitted in a given time by a given area. It is independent of the length of the heat patch, that is, the thickness of the material.

Conduction.—The transfer of heat between two bodies or parts of a body which touch each other. Internal conduction takes place between the parts of one continuous body, and external conduction through the surface of contact of a pair of distinct bodies.

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Conductivity.—The quantity of heat transmitted through a unit thickness of material per unit of area in a unit of time. In the English system of measures, the conductivity is usually expressed in Btu per hour per inch of thickness.

Convection.—The transfer of heat by means of utilization of the fact that warmed particles of gases or liquids rise and cooled particles of gases or liquids fall.

Core.—The body of water, usually containing concentrated impurities, in the center of a partially frozen block of ice before the final freezing of all the water in the ice can. The original core water is withdrawn by means of a core sucker and the cavity filled with fresh water with a core filler.

Core filler.—The unit consisting of a flattened tube and an automatic (self-closing) valve at its top for refilling the core cavity and washing away possible foreign matters from the top of ice blocks.

Core pump.—The appliance for withdrawing the concentrated impurities in the center of an ice block by pumping a vacuum through the core suction line, hose, and core sucker.

Core sucker.—A flattened tube inserted into the core to remove the impure water, with the aid of a core pump, from the center of an ice block.

Density.—The mass or quantity of matter of a substance per unit of its volume; proportional to the specific gravity, since mass is proportional to weight.

Dew point.—Temperature point at which moisture vapor will begin to condense, at this point the air is also saturated.

Drop tubes (perforated).—The brass tubes used in a low-pressure system for producing ice of the most transparent quality with the minimum amount of white core. The perforations are scientifically calculated and spaced on the side of the tube to insure producing ice of the highest quality.

Drop tubes (freeze- in type).—The brass tubes used in high- and low-pressure systems to obtain ice of the best quality. They are for conveying the air to each ice can and to the center of the can and are removed after the ice block has been solidly frozen.

Efficiency, mechanical.—A term intended to express the ratio of indicated horsepower to that available for doing work. Brake horsepower divided by indicated horsepower gives the mechanical efficiency.

Efficiency, volumetric.—This term may be defined as the ratio of the volume of refrigerant actually removed, reduced to the condition of temperature and pressure of the evaporator, to the volume of piston displacement.

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Element.—An element contains only one kind of substance and cannot be decomposed.

Entropy.—An index of the relative amount of unavailable energy in a physio-chemical system. Known as the thermodynamic function.

Evaporator.—A piece of refrigerating equipment that receives the liquid refrigerant and into which the heat, from the commodity to be refrigerated, passes; evaporating the refrigerant.

Expansion valve.—A term generally applied to a valve located in the liquid line at the evaporator, to control the rate of flow of liquid refrigerant.

Force.—That which tends to produce or destroy motion.

Framework.—An arrangement of wood stringers lengthwise over the freezing tank with wood spacer between them and sufficiently spaced to comfortably admit the ice cans in the tank.

Freezing tank.—The large container built in an ice-making plant, to hold the circulating or agitated brine into which the ice cans are submerged.

Fusion.—This term differs in meaning when used in two different types of work. In a discussion of a change of state of a substance from a liquid to a solid the process is called fusion. In a discussion of a welding process in which similar metals are melted, mixed, and allowed to solidify together, the process is called fusion, in contrast with a soldering or a brazing process on steel or iron.

Halid torch.—A torch used for detecting leaks in systems using the following refrigerants: methyl chloride, freon, etc. These torches may burn alcohol, acetylene, or gasoline depending on design.

Harvesting.—The act of gathering or removing the finished ice blocks from the cans in the freezing tank.

Head of water, static.—The height of water above a given point from which the pressure is measured; it is usually expressed in feet and inches.

Heat, latent.—The quantity of heat required to change the physical state of a body without a change of temperature. It requires 144 Btu per pound to change 32° ice into 32° water; this is known as the latent heat of fusion. It requires 971.7 Btu per pound to change water into steam without changing temperature; this is known as the latent heat of evaporation of water at atmospheric pressure.

Heat, sensible.—The heat required to change the temperature of a body without changing its physical state.

Heat, specific.—The amount of heat required to change a pound of a substance 1° F., without a change of state.

Heat transfer coefficient.—The quantity of heat transmitted through a unit thickness of substance per unit of area in a unit of time. It

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is usually expressed in Btu per square foot per hour per degree temperature difference per inch of thickness.

High pressure air.—The conditioned air used in high pressure clear raw water ice systems at about 15 pounds per square inch for ice cans up to 61 inches deep.

Horsepower.—A unit of power or rate of performance of work. Normally given as 33,000 foot-pounds per minute.

Hose couplings.—The brass fittings used to receive rubber tubing, making connections with it to the drop tubes in the ice can.

Humidity.—The moisture or aqueous vapor in air which expands with heat and contracts when cooled.

Hygrometer (psychrometer).—An instrument for measuring the humidity in the air, with wet bulb and dry bulb thermometers.

Ice can.—The mold, usually made of galvanized steel, into which is placed the water to be frozen into ice. Ice cans are submerged in the brine of the freezing tank.

Infiltration.—This term is loosely applied in refrigeration work to the wall heat leakage and heat-in-air leakage.

L. C. L.—These initials are for the words, "Less than carload lots", which is a term used in freight rate calculations; an abbreviation.

Low pressure air.—The air used in low pressure clear raw water ice systems at about 1¾ pounds per square inch pressure for ice cans 44 inches to 48 inches deep.

Manifold.—This may be used verbally or as a noun, normally to denote a grouping of valves, all operating on one line, or a group of tubes or pipes; all making adjacent "tee" connections in one other pipe.

Mass.—The quantity of matter which a body contains. Frequently known as the product of its volume and its density.

Mechanical joint.—This term, as used in refrigeration work, applies to a pipe or tubing connection that can be made or broken and remade by use of wrenches. A threaded or flanged joint would be a mechanical joint.

Mercury gage.—The instrument for reading the air pressure accurately by ounces. It is generally used on all low-pressure air agitation in clear raw water ice systems.

Micrometer.—A device for measuring distances, thickness, diameters, etc., in thousandths of inches. An inside micrometer would be used to accurately determine the base of a cylinder of 10.016 inches. A small outside micrometer would be used to measure the thickness of sheet metal of .0625.

Ohm.—The unit of electrical resistance.

Power.—The rate at which work or mechanical energy is performed.

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Pressure.—The force uniformly applied over an area. The unit of pressure in general use is pounds per square inch above the atmospheric pressure and is known as gage pressure. Atmospheric pressure added to gage pressure equals absolute pressure.

Pressure relief valve.—A safety device to prevent excessive pressure in a refrigeration system. It is usually a spring loaded valve located in the high-pressure line, and so adjusted that at a predetermined pressure the valve will open, allowing the high-pressure gas to escape in the atmosphere, or to the low-pressure part of the system.

Pressure vessel.—An inclosed cylinder, pipe, coil, tank, or assembly of such items capable of holding gases under pressure.

Psychrometry.—A term denoting the physical characteristics of air in relation to the moisture content at different temperatures and pressures.

Pulling.—The act of removing ice cans from the freezing tank.

Quality.—The dryness of vapors, expressed in percentage, as 60 percent vapor, 40 percent moisture.

Radiation.—The transfer of heat between bodies separated from each other by an appreciable distance. The transfer of heat between two distant bodies, through an intervening medium without heating the medium. As an example, the sun heats the earth without heating the air between.

Receiver.—A pressure vessel, usually cylindrical in form, used in a refrigeration cycle to receive liquid refrigerant from the condenser and supply liquid to the liquid line, meanwhile retaining excess liquid refrigerant. Receivers often have a sight gage glass to show amount of liquid refrigerant within.

Refrigerant.—In this work, "refrigerant" applies to a liquid of low boiling temperature.

Refrigerating effect.—Ability of a refrigerant to absorb Btu. The amount of heat a pound of refrigerant can absorb in vaporizing is known as the heat of vaporization per pound.

Refrigeration.—The process of removing heat.

Relative humidity.—The ratio of the actual quantity of moisture in the air to the quantity that would saturate the air under its actual conditions as to pressure and temperature. Relative humidity is usually expressed in percentage.

Relay.—A term used to denote an electrical device, usually magnetic, that will close an operating switch. Sometimes this term applies to a temperature-controlled electrical device used to open a safety switch to prevent overloading of electrical equipment or circuits.

Saturation.—A condition of the air, such that it can hold no more moisture.

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Service valve.—A valve used for servicing operations, usually on small units, at junctions of the suction lines and discharge lines with the compressor cylinder. These valves are normally supplied with plugged tapped holes for connecting gages, charging lines, etc.

Solder.—Used as a noun, this denotes a metallic mixture of lead and tin that has a low melting point. Used as a verb this applies to the process of applying this metal to joints of pieces of metal of higher melting points to make a connection between them.

Specific gravity.—The ratio of the weight of a given body to that of an equal volume of water.

Specific volume.—The volume of 1 pound of a substance.

Standard ton conditions.—An evaporator temperature of 5° F. and a condenser temperature of 86° F.

State.—This applies to the physical condition of a substance such as solid state, liquid state, and gaseous or vapor state.

Sublimation.—This is a physical phenomenon or some substance under some conditions in which the substance changes from a solid state directly into a vapor without ever being in a liquid state.

Synchronous motor.—An electric motor whose speed is exactly determined only by the number of pairs of poles in the motor and the frequency of the line current. Its power factor can be controlled and can be used to balance its leading power-factor ability against the lagging power factor of induction type motors thus giving a more electrically efficient total circuit condition.

Tachometer.—An instrument for indicating the revolutions of a machine. Sometimes known as a speed indicator.

Temperature.—This is the registration of sensible heat or the indication of sensible heat intensity.

Tensile strength.—The force per unit area required to rupture by tension.

Thawing needle.—A small hollow tube to pass water through it when it is inserted into drop tubes that are frozen into a block of ice for the purpose of removing the drop tubes.

Thawing tank.—The container in which ice blocks are loosened from the ice cans by means of slightly warmer water. Sometimes known as a "dip tank".

Thermo-dynamic.—Of or pertaining to the transfer of heat energy into motion, or to the relation between them.

Thermostat.—A device sensitive to temperature and capable of transmitting changes within itself to a motor or valve or other piece of equipment.

Ton of refrigeration.—The removal of 200 Btu of heat per minute.

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Tubing.—Hollow, cylindrical material used to convey liquids or gases. Steel tubing of large diameter is usually called pipe. Copper or brass tubing is generally used.

Tubes, stationary.—The air tubes used in high pressure air agitation systems for producing transparent ice. They are fastened to the sides of the ice can, either inside or outside.

Vacuum.—A space entirely devoid of matter.

Vaporization.—A change of a substance from a liquid state into a vapor.

Velocity.—The distance and direction in which a body moves in a given time. Speed per second of object involved.

Volt.—The unit of electro-motive force, electrical pressure, or difference in potential.

Water.—Pure water is a chemical compound (H_2O) formed by the union of two volumes of hydrogen gas with one volume of oxygen gas, or two parts by weight of hydrogen and sixteen parts by weight of oxygen.

Watts.—The unit of electrical power equal to volts multiplied by amperes in direct current circuits.

Wet bulb depression.—The difference between the wet bulb and dry bulb thermometer readings.

Work.—The overcoming of a resistance through a given space. It is measured by the amount of resistance multiplied by the distance through which it is moved.

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Appendix II

TROUBLE DIAGNOSIS CHART

Trouble	*Probable cause*	*Corrective measures*
High head pressure.	Air or noncondensable gas in.	Purge air from receiver.
	Inlet water warm.	Increase quantity by adjusting water regulating valve. Use larger valve if necessary.
	Insufficient water flowing through condenser.	Readjust water regulating valve by loosening adjusting screw.
	Condenser clogged or limed from hard water.	Clean condenser water tubing with inhibited acid.
	Too much liquid refrigerant in receiver.	Draw off gas into service drum, condenser tubes submerged in liquid refrigerant.
	Insufficient air circulation. (Air cooled.)	Remove obstruction, change fan blade, pitch, clean condenser of lint.
Low head pressure.	Too much water flowing through condenser.	Regulate water valve.
	Water too cold, unthrottled.	Reduce quantity of water.
	Liquid refrigerant flooding back from evaporator.	Change expansion valve adjustment, examine fastening of thermal bulb.
	Leaky discharge valve.	Test with gages; if leaking, replace.
High suction pressure.	Overfeeding of expansion valve.	Regulate expansion; check bulb attachment.
	Compressor too small for evaporator or load.	Check capacity, try to speed up if possible or increase compressor size.
	Leaky suction valves.	Remove head, examine valve disks, or rings; replace if worn.

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Trouble	*Probable cause*	*Corrective measures*
Low suction pressure.	Restricted liquid line and expansion valve or suction screens.	Pump down, remove, examine and clean screens.
	Compressor too big for evaporator.	Check capacity against load, reduce speed if necessary.
	Insufficient gas in system.	Check for gas shortage at test cock.
	Too much oil circulating in system.	Check for too much oil in circulation. Remove oil.
	Improper, or too small, adjustment expansion valves.	Adjust valve to give more flow; if opening valve does not correct, increase size to give greater capacity.
Compressor short cycles.		
On high pressure cut-out.	Insufficient water flowing through condenser; clogged condenser.	Determine if water has been turned off. Adjust water regulating valves. Check for limed up condenser.
	High pressure cut-out incorrectly set; low pressure adjusted incorrectly.	Check setting of high pressure cut-out; switch should throw out at 20 pounds greater than normal running head pressure. Check switch settings.
	System overcharged with refrigerant.	High pressure cut-out may be tripping due to insufficient condenser capacity because condenser tubes are submerged.
On low pressure cut-out.	Fans not running on cold diffuser or weathermaker.	Check all electrical connections, fuses, thermal overloads, thrown switches.
	Coils on evaporator clogged with frost.	Defrost coil. Refer to sections 15Y–Z and 39Y–Z for further corrective measures. Check switch settings; cut-out point should

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Trouble	*Probable cause*	*Corrective measures*
		be set 1 to 2 pounds lower than normal operating back pressure.
	Liquid, suction or expansion valve screens plugged.	Pump down and clean screens.
	Compressor too large for load.	Slow down compressor by decreasing motor pulley size.
	Discharge valve leaks slightly.	Test valve. If leaking remove cylinder head, examine, replace if necessary.
	Thermal bulb on expansion valve has lost charge.	Detach thermal bulb from suction line and hold in the palm of one hand, with the other hand gripping the suction line; if flooding through is observed, bulb has not lost its charge. If no flooding through is noticed, replace expansion valve.
On thermostat.	Room thermostat in path of cold air.	Remove thermostat so that it is in the path of the return air.
Compressor runs continuously.	Shortage of refrigerant.	Test at refrigerant test cock; if short of gas, add proper amount necessary. Test for leaks.
	Compressor too small for load.	Capacity must be increased by increasing speed or using larger compressor.
	Discharge valve leaks badly.	Test valve; if leaking, remove head of compressor and repair or replace.
	Correct estimating and selection.	On air conditioning service, compressor should run continuously under certain air conditions.

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Trouble	*Probable cause*	*Corrective measures*
Compressor noisy.	Vibration because not bolted to rigid foundation.	Add mass to foundation; bolt down rigidly.
	Too much oil in circulation causing hydraulic knock.	Check oil level; check for oil at refrigerant test cock; check other symptoms on oil chart.
	Oil slugging while operating due to too much oil or refrigerant flooding back to compressor.	Same treatment as above.
	Slugging due to flooding back of refrigerant.	Expansion valve open too wide, close. Thermal bulb incorrectly placed or loose, check. Loop suction line so refrigerant will not flood back on off cycle.
	Wear of parts such as piston, piston pins, eccentrics, etc.	Determine location of cause. Repair or replace compressor.
Flywheel wobbles.	Mistreatment on installation, due to severe slugging when evacuating.	Shaft may be twisted at key, check. No correction possible unless shaft is replaced. If wobble not too great, no objectionable belt wear will result. Remove flywheel, clean flywheel bore and shaft to determine if particle of dirt is causing condition.
	Mishandling in shipment; may be bent shaft.	Make claim for hidden damage with transportation company, drop of one foot or more liable to cause condition. Also remove flywheel, clean bore and shaft of possible dirt particles.

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Trouble	*Probable cause*	*Corrective measures*
Oil leaves crankcase.	Too much refrigerant flooding back.	Readjust expansion valves, check thermal bulbs for proper mounting, place inverted U loop in suction line.
	Expansion valves leaking.	Valves may be wire drawn on needle and seat from passage of vaporous refrigerant through valve due to low refrigerant charge. Check valves, replace valves if necessary.
	Improperly installed suction.	Reinstall suction line to contain inverted U to be at least level with top of coil.
	Leaking piston rings or worn cylinder.	Replace rings or compressor, or rebore and refit.
Oil does not return to crankcase.	Oil check valve stuck shut.	Remove external check valve. Gate should swing freely; if not, burs on hinge pin hole may be causing trouble; remove these.
	Expansion valve not flooding coil.	Adjust to flood coil.
	Flooded system. No oil bleeder line.	Install and adjust oil bleeder line.
Water valve chatters.	Water pressure too high.	Install water pressure reducing valve.
	Water valve too large in capacity.	Stem may be hitting seat because valve throttled low. Install smaller valve.
	Air in the lines.	Install air chamber at high point of piping to eliminate water hammer.

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Trouble	*Probable cause*	*Corrective measures*
	Pulsating from discharge pressure fluctuation.	Connect refrigerant line to bellows of valve to source of constant pressure such as liquid valve or line so that pulsating effect of compressor piston is not transmitted to valve operating mechanism.
Water runs continuously.	Water valve open too wide.	Readjust valve to give correct head pressures corresponding to water inlet temperature and condensing temperature.
	Dirt under seat of water valve.	Remove valve from lines, disassemble, examine, and replace defective parts; clean and reassemble. If valve then does not function properly, replace.
	Valve mechanism stuck.	Remove and disassemble. Clean valve seats, valve pins, etc.
	Water temperature too high for valve setting.	Consult chart in this section.
Motor blows fuses; trips overload.	Fuses too small; overload too small.	Check fuse and overload heater element sizes against full load motor current. Install larger sizes if necessary within safe limit for motor. Check temperature of machine room; this may be high, thus not allowing sufficient margin for heating of overload heater element. Use larger element where necessary because of this condition, but not too large to lose motor protection.

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Trouble	*Probable cause*	*Corrective measures*
	Poor switch contacts.	Arcing or burned switch contacts may need replacement. Check carefully. Replace contacts or entire switch where necessary.
	Low voltage.	Check voltages with meter; if more than 10 percent low, notify power company to correct condition.
	Leaky discharge valve.	Test discharge valve; if leaky, replace because this puts heavy load on motor when starting up because of heavy pressure over piston.
	Overload motor.	Check Bhp load against back pressure and compressor speed; if motor too small, increase size.
Motor hot.	Low voltage.	Check voltage with meter; if more than 10 percent low, notify power company to correct condition.
	Oil.	Bearings should be oiled to reduce friction.
	Overloaded.	Check Bhp load against back pressure speed.
Compressor will not start.	Thermostat set too high; thermal bulb has lost charge.	Check position of temperature indicator, it may have been moved. Check for discharged thermostat bulb.
	Overload tripped; fuses blown.	Reset overload; replace switches and examine for cause of condition as listed under "motor blows fuses."
	Switch out.	Throw in switch.
	No charge of gas in system operated by low-pressure control.	With no gas in system, there is insufficient pressure to throw in low-pressure control. Recharge system with gas; stop leaks.

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Trouble	*Probable cause*	*Corrective measures*
	Solenoid valve closed.	Examine holding coil; if burned out or defective, replace.
	Dirty contact points on controls.	Contacts will not allow current to flow, clean contacts.
Head gasket leaks.	Head bolts stretched or washers crushed.	Examine gaskets; replace if necessary. Tighten head bolts. Replace washers.
	Oil slugging.	Check operating conditions, flooding of refrigerant to crankcase. Examine for conditions on refrigerant and oil chart. Correct.
Cylinders and crankcase sweating.	Too much oil in circulation. Too much refrigerant in circulation.	Examine for conditions on refrigerant and oil charts. Correct anything found wrong.

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APPENDIX III

TEST FOR EFFICIENCY OF EXPANSION VALVE

It is a simple matter to test out expansion valves in the field. In most cases the regular service kit contains all the necessary equipment. The equipment required is as follows:

1. Service drum full of Freon or methyl chloride (in the shop a supply of clean dry air at 75 to 100 pounds pressure can be used in place of the service drum). The service drum is merely for the purpose of supplying pressure and for this reason the refrigerant used does not have to conform with the valve being tested; in other words, a drum of Freon would be perfectly satisfactory for testing with SO_2, methyl chloride, or Freon valves.

2. A high-pressure and low-pressure gage. The low pressure gage should be accurate and should be in good condition so that the pointer does not have too much lost motion. The high pressure gage is not absolutely necessary but is recommended so as to show the pressure on the inlet of the valve.

3. Fittings and connections are required to complete the hook-up as shown in figure 25.

4. A small quantity of finely crushed ice is necessary and one of the most convenient ways of carrying this around is to keep it in a thermos bottle. If such a container is completely filled with crushed ice it will last easily for 24 hours. Whatever the container is it should be completely filled with crushed ice. Do not attempt to make this test with the container full of water and a little crushed ice floating around on top.

Freon	22 pounds.
Methyl chloride	15 pounds.
Sulfur dioxide	3 pounds.

These pressures are equivalent to an evaporating temperature of 22° F. and since the crushed ice maintains the bulb at 32° F. there is a difference of 10° or, in other words, the valve adjustment is for 10° superheat. This has been found desirable for practically all types of installations. Be sure to have a small amount of leakage through the gage connection while making this adjustment.

5. Tap the body of the valve lightly with a small wrench in order to determine if the valve is smooth in operation. The needle of the gage should not jump more than 1 pound.

6. Screw the gage up tight so as to stop the leakage through the

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threads and determine if the expansion valve closes off tightly. With a good valve, the pressure will increase a few pounds and then either stop or build up very slowly. With a leaking valve the pressure will build up rapidly until it equals the inlet pressure.

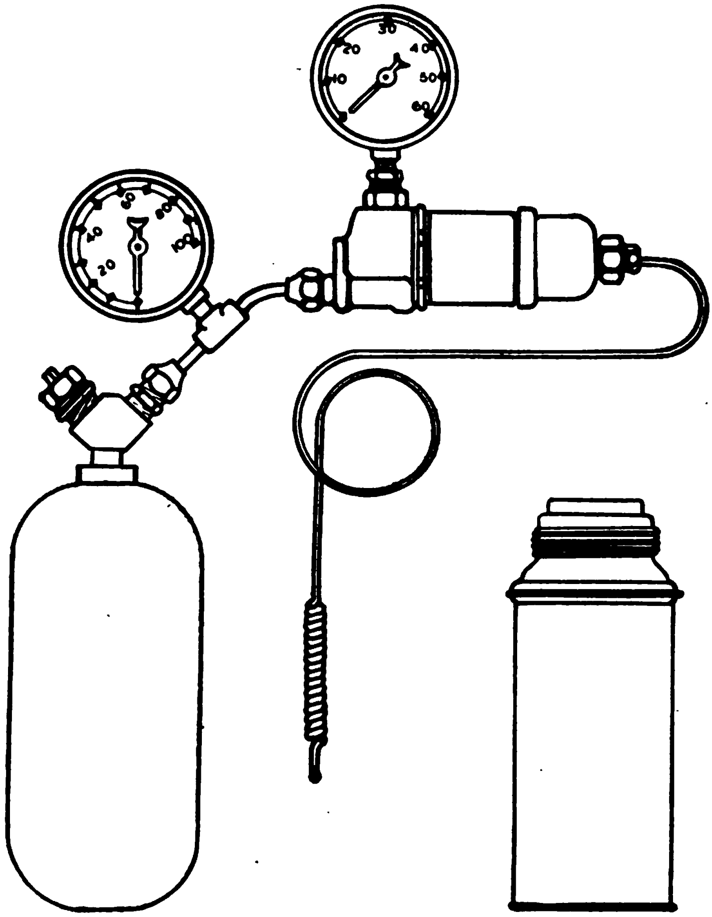

FIGURE 25.

PROCEDURE

1. Connect up the valve as shown with the low-pressure gage screwed slightly loose into the adapter on the expansion valve outlet. The gage is screwed up loosely so as to provide a small amount of leakage through the threads.

2. Insert the bulb in the crushed ice.

3. Open the valve on the service drum and be sure that the drum is warm enough to build up a pressure of at least 70 pounds on the high-pressure gage connected in the line to the valve inlet.

4. The expansion valve can now be adjusted. The pressure on the outlet gage should be different for various refrigerants as follows:

PRECAUTIONS

1. Be sure that the service drum has liquid in it and is warm enough to build up sufficient pressure. The high-pressure gage used as shown in the figure will often save a lot of trouble because it will show when there is not enough pressure on the inlet side of the valve. During winter especially, the service drum may become cold and develop insufficient pressure to make a satisfactory test.

2. Be sure that the thermos bottle or other container is full of finely crushed ice and does not have merely a little ice floating on top of the water.

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7. Again loosen the gage so as to permit leakage through the threads and then remove the feeler bulb from the crushed ice and warm it up with your hand or by putting it in water at about room temperature. The pressure should increase rapidly showing that the power element has not lost its charge. If the pressure does not increase when this is done it is a sign that the power element is dead.

8. With high pressure showing on both gages as outlined in paragraph 7, the valve can be tested to determine if the body bellows leaks. This should be done by loosening up the packing nut and using a Halide leak detector to detect the escape of gas. When making this test it is important that the body of the valve have a fairly high pressure on it and also that the gage and other fittings are screwed up tight so as to eliminate leakage at other points. Leakage can also be detected by the use of oil or soap suds.

9. On valves for low temperature applications, such as ice cream cabinets, the maximum operating pressure determined by the gas charge is too low to be tested with the bulb at 32° F. These valves should be tested with the feeler bulb at 5° F. and adjusted to the following pressures:

Sulfur dioxide	12 inches.
Methyl chloride	2 pounds.
Freon	7 pounds.

In order to test sulfur dioxide valves it becomes necessary to incorporate in the test set-up a vacuum connection between the valve outlet and the gage. This connection should be provided with a needle valve and the expansion valve setting determined by the pressure observed immediately after the needle valve is closed off. When using the vacuum connection, the gage and other connections must be tight and there should be no restrictions between the valve outlet and the gage.

[A. G. 062.11 (4–6–43).]

BY ORDER OF THE SECRETARY OF WAR:

G. C. MARSHALL,
Chief of Staff.

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(For explanation of symbols see FM 21–6.)

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